ABSTRACT

The Orange Water & Sewer Authority (OWASA) contracted with the Department of Environmental Sciences & Engineering to conduct a two-stage study involving current water consumption. This study is intended to help OWASA determine conservation and pricing strategies in accordance with their Comprehensive Water & Sewer Master Plan. The goal in Phase I, described in this technical report, is to understand residential consumption. Preliminary screening and analysis was performed in Phase I that will help guide the content in Phase II. This report addresses patterns of residential water consumption and uses a linear regression model to identify factors related to consumption and assess effects of passive conservation.

Residential users consume an average of approximately 6,000 gallons per month per household. Single family households use almost 60 percent more water than multi-family housing units. Summer outdoor use accounts for approximately 55 to 60 percent of the total use for multi and single family households, respectively.

Factors significantly associated with monthly consumption include the assessed value of the house, property area, type of housing unit, whether or not the house was constructed before 1994, average monthly temperature, and the number of days of precipitation per month.

Passive conservation, which is the reduction in consumption due to water-saving devices, was prompted by the plumbing code regulations in 1994 that require new homes to contain more efficient fixtures. Houses constructed before 1994 consume approximately 500 gallons per month per household more than those built after the 1994 regulations.

Further work is needed to verify results from Phase I. Some of the tasks may include collecting additional secondary data on house construction date, collecting primary data via a household survey, and assessing the validity of the Aquilium database.

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1.0 Introduction and Background

"When the well's dry, we know the worth of water." - Ben Franklin

Large portions of the United States, including North Carolina, are fortunate to possess seemingly plentiful supplies of water – a precious resource that is often taken for granted. Until the 1950s, the policy in the United States was to provide infrastructure for water supply, and the era of building large dams produced copious sources of water for even the most arid regions. But the ability to increase supply was not endless (USGS, 1996), and the need to balance water demand with available supply is highlighted by recent droughts across the country. Over time, with booming growth and increases in population, water consumption is rapidly approaching the available supplies even in North Carolina (Moreau, 1992).

1.1 Project Background

The Orange Water and Sewer Authority (OWASA) maintains an existing raw water supply system in Orange County, North Carolina, that consists of University Lake, Cane Creek Reservoir, and Stone Quarry Reservoir, the characteristics of which are summarized in Table 1.1.

Table 1.1 – Characteristics of Existing OWASA Supply Sources

Source	University Lake	Cane Creek	Quarry Reservoir
Year Developed	1932	1989	1979
Usable Volume (billion gallons)	0.45	2.98	0.20
Surface Area at Full Volume (acres)	212	500	10
Average Inflow (million gallons/day)	18.9	20.1	<0.1

Source: Holland, 2000

OWASA began examining its fundamental needs in 1998 by initiating studies for their Comprehensive Water & Sewer Master Plan. According to the OWASA report titled "*Water Supply: A 50-Year Vision for The Community*," analyses concerning the safe yield of the local raw water supply facilities indicate that the 30-year safe yield of the existing raw water system is approximately 11.2 million gallons per day (mgd). This yield is not expected to meet future water needs; therefore, several expansion options were considered. The selected option involves increasing Stone Quarry storage volume to 3.0 billion gallons (bg). This additional capacity would increase total system safe yield to 20.5 mgd and would likely meet projected water needs until 2050 (Holland, 2000).

In addition to increasing the capacity of the current water supply system, OWASA is concerned with new methods of approaching water supply and demand. Another component of the master planning study concerned more sustainable demand-side management to establish the impact of conservation measures over the 15- and 50-year planning periods. Reduced demand is resulting from improved water-use efficiency, conservation, recycling, and reuse rather than the development of structural projects for increased supply.

An example of enhanced efficiency is the implementation of low-flow toilets and showerheads. Since the early 1980's, high efficiency toilets that use only 1.6 gallons per flush (gpf) or less have been in the U.S. market (EPA, 2001). Older, conventional toilets consume water at the rate of five to seven gallons per flush. In North Carolina, the plumbing code for new construction was changed for residential toilets to reduce the volume to 3.5 gallons per flush in the 1980s. The code was then revised again in the early 1990s to further reduce the volume to 1.6 gallons per flush (Moreau, 1992). Seventeen states, including North Carolina, had mandated by 1992 that a low-flow standard be established for replacement toilets and new construction. On the national level, the Energy Policy Act of 1992, which was effective on January 1, 1994, established manufacturing standards for plumbing fixtures (EPA, 2001). Federal energy and water efficiency standards are now required for toilets (1.6 gpf) and other products such as showerheads (2.5 gallons per minute, gpm) that are installed in any new home or building (ENN,1999).

Another water management approach, conservation, is coming to the forefront of water supply planning in many communities. Both passive and active conservation lead to reductions in operating costs of both water and wastewater facilities and to the delay of capital outlays necessary for expansion of supply capacity (Moreau, 1992), which are benefits to both the consumers and the water utility.

Passive conservation is associated with reduction in water use attributed to the improved efficiency of water-using devices due to recent plumbing standards; it requires no action by either the water utilities or the consumer. Some active strategies that have been used include educating the public about conservation, increasing water prices, and rationing (Ushikubo, 1999). Public education is often accomplished by informing the community of the limits in supply and giving them guidance on how to reduce consumption (e.g. sustainable irrigation techniques, household water saving practices). Pricing changes, which can be easier to put into practice than educational campaigns, typically result in reduced water use. Rationing (when enforced) can result in substantial reductions in consumption.

In order to effectively bring conservation to fruition, understanding residential water use is of paramount interest to utilities such as OWASA, local and regional planners, and policy makers alike. This thesis is concerned with the examination of residential water use within the OWASA service area of Chapel Hill and Carrboro.

In Chapel Hill and Carrboro, water use is measured through customer meters that OWASA reads monthly. The determinants of consumption, which typically include variables such as household size, income, lot size, and weather conditions, are useful when trying to target households for conservation programs. Unlike total monthly consumption that is directly measured, the effect of these determinants specific to our service area is not well known but would be useful when planning or implementing policy such as water conservation. Accurately measuring, analyzing, and modeling consumption in the residential sector improves the effectiveness of conservation efforts.

1.2 Project Motivation

In 1999 and 2000, the consulting firms of CH2M-Hill and Planning and Management Consultants, Ltd (PMCL) submitted several technical memorandums to OWASA as part of a series of reports in the process of preparing OWASA's

Comprehensive Water and Sewer Master Plan. The technical memorandums contain background information regarding OWASA's service area as well as preliminary water use data and forecasting models for future consumption. Recommendations from the three reports (Technical Memorandums 3.1, 3.2 and 3.3), summarized below, prompted this research.

In June 1999, CH2M-Hill submitted Technical Memorandum 3.1 – *Water Demand Forecasts* (TM3.1) to OWASA, which is concerned with forecasting OWASA's demand into the future. The document contains a description of OWASA's service area and its characteristics, water demand forecasting methods, an analysis of historical OWASA consumption data, and the application of water demand forecasting methods to supply planning and management. TM3.1 covers the three primary customer sectors: 1) residential, 2) university/UNC hospitals, and 3) commercial/other. The focus of this report is on residential consumption.

According to TM3.1, residential consumption is almost evenly divided between single and multi-family use, and it accounts for approximately half of OWASA's average demand, which was 7.58 million gallons per day (mgd) in 1998. TM3.1 summarizes water use between fiscal years 1992 through 1998, as shown in Table 1.2 below (CH2M-Hill, 1999). The focus of this study is on single family and separately-metered multi-family residential households.

Table 1.2 – TM3.1: Residential Consumption by OWASA Customers 1992 – 1998

Household Type	Number of Customers (1)	Average Consumption (mgd) (2)	Percent of Total Demand
Single family	11,091	1.96	26 %
Multi-family (separately metered)	3,218	0.40	5 %
Multi-family (master metered)	377	1.44	19 %
Total	14,686	3.80	50 %

(1) As of June 30, 1998
(2) Averaged over the fiscal years from 1992 though 1998

CH2M Hill and PMCL jointly submitted Technical Memorandum 3.2 (TM3.2) – *Baseline and Alternative Water Demand Forecasts* to OWASA on September 19, 1999. Water demand information from TM3.1 is revised in TM3.2 to incorporate updated demographic, consumption, and meteorological data and then used to model and produce baseline and upper and lower (alternative) forecasts for water demand over a 50-year planning period. A linear regression model was also reported in TM3.2 to gauge the relationship between water use and seasonal/climate variation. CH2M-Hill and PMCL (1999) developed the baseline and alternative models using default values from the model software package for most of the parameters, adjusting for weather departure data and the number of single and multi-family housing units for the years 1995, 1996, and 1997.

Table 1.3 summarizes the average, minimum and maximum water use *per household* for both single and multi-families from TM3.2. The water use for single-family homes exhibited a distinct seasonal pattern with peaks from June through September annually, as well as variations influenced by weather. The multi-family group did not vary much either seasonally or with weather changes, although it typically peaked annually in September.

Table 1.3 – TM3.2: Average Residential Consumption Per Household (1)

Household Type	Average Consumption per Household (gal/day)	Minimum Consumption per Household (gal/day)	Maximum Consumption per Household (gal/day)
Single family	199	140 (January 1995)	278 (September 1997)
Multi-family	125 (2)	118 (3) (March 1997)	155 (3) (September 1997)

(1) Averaged over the period of July 1991 through June 1998
(2) Separately metered households
(3) Both separate and master-metered households

Indoor water use is estimated by using the month during which minimum consumption occurs during the year. This method is commonly used and is widely accepted to be reliable, with two noted exceptions: indoor water use may vary seasonally, and some outdoor water use may be included in the minimum monthly consumption.

PMCL and CH2M Hill jointly submitted Technical Memorandum 3.3 – *Long-Term Water Demand Forecasts with Conservation* (TM3.3) to OWASA on January 24, 2000. The report focuses on the impact of conservation on future water consumption, and analyzes the costs and benefits of alternative demand management strategies over a 50-year planning period.

TM3.3 states that the impact of passive conservation (i.e. new plumbing standards and improved efficiency) is estimated to reduce water consumption in 2050 (as projected from baseline estimates in TM3.2) to 15.2 mgd. This reduction translates to an *18 percent decrease* from the estimated raw water demand without conservation. By implementing active conservation (i.e. accelerating the replacement of older less-efficient fixtures), the raw water demand is estimated to be further reduced to 14.9 mgd in 2050, an overall decrease of 20 percent. These dramatic reductions in water consumption could lead to the deferment of the Stone Quarry reservoir expansion option as much as 20 years; however, the baseline predictions for the year 2050 from TM3.2 may not be very reliable, especially since general default values are used in the model for making predictions.

In the findings and recommendations in TM3.3, CH2M-Hill comments that many of the assumptions upon which the results are based are "derived from secondary sources (such as similar studies from other areas), and many of the assumptions are presumably reasonable but are unsubstantiated" (CH2M-Hill and PMCL, 2000). Based on the fact that the analysis in TM3.3 is – self-reportedly – fairly uncertain, some of the consultants' recommendations are based on validating the results with further research that includes field studies as well as the collection of data from existing OWASA customers.

1.3 Project Objectives

This research is concerned with verifying and fine tuning some of the findings from the Technical Memorandums described in Section 1.2. In particular, items from TM3.3 that are addressed in this study include:

(1) Patterns of residential water use

(2) Determinants of residential water consumption

(3) Effects of passive conservation

Patterns of local residential water use (Objective 1) that relate to seasonal consumption, housing type, and spatial distribution are important for OWASA because of their economic and engineering implications. Monthly consumption is often correlated with seasons, with lowest use in the winter months and highest use in the summer months. Winter consumption is coupled with indoor water use, whereas summer consumption is representative of the indoor and additional outdoor uses associated with irrigation and other summer activities, such as pools and fountains. It is interesting to note that TM3.2 shows that the peak annual consumption occurs in September for the year 1997 (Table 1.3).

For patterns associated with housing type, detached single-family households typically use more water than multi-family dwellings. Often this can be attributed to the fact that there is less of a seasonal variation, as many multi-family units do not have properties that they need to irrigate in the summer months. The spatial distribution may also show signs of significant variability in water use.

The impact of seasonal patterns on revenue and pricing is an important topic, especially because OWASA is currently considering seasonal water rates, as shown below in Table 1.4 (OWASA, 2001). It is important to determine both the seasonal and housing type effects before fully implementing new water policies for the local residents. OWASA wants to know not only which customers are affected, but also by how much.

Table 1.4 – OWASA's Current and Proposed Seasonal Water Rates

	Months	Rate
Current	All Months	Uniform rate $2.90 per 1,000 gallons
Proposed	October – April	Winter rate – lower $2.16 per 1,000 gallons
	May – September	Summer rate – higher $4.08 per 1,000 gallons

The engineering implications are also critical to the planning process. With variations in water consumption over time and space, capacity planning becomes more difficult. To effectively plan, accurate information is needed concerning not only the extent of peak demands in the summer months for different types of households, but also where in the system these peaks occur.

To further understand the variability in water consumption, Objective (2) focuses on determining the main variables that drive residential consumption. This objective is aimed at a more refined understanding of residential water use, which is approached by identifying the determinants of consumption. Independent variables that may influence consumption include lot size, number of bathrooms, construction date of house, precipitation, and temperature, as well as the type of household for which patterns are established in the first objective. This objective looks at how these variables affect water consumption – both by degree (i.e. the magnitude of the effect) and direction (i.e. positive or negative effect).

Once the main components of water use are determined, the issue of passive conservation in Objective (3) can be addressed. With the 1994 change in the plumbing code, as discussed in Section 1.1, it is not realistic to simply project historical consumption trends into the future because the quantity consumed may be reduced with the use of water-saving devices. The forecasting implications affect economic and engineering planning. If household consumption changes, then the revenues and the total capacity needed for the system are altered. The effect of the changes due to passive conservation can be observed by comparing the houses constructed before and after the plumbing code regulations were instituted. This study attempts to identify the per household effects of passive conservation, but it is not concerned with forecasting these effects on OWASA demand in the future.

1.4 Project Methodology

In order to achieve these objectives, the following tasks are needed:

(1) Collect data
(2) Create database
(3) Analyze preliminary patterns
(4) Conduct statistical regression analysis
(5) Interpret and present findings

The baseline information is residential water consumption, which is obtained from OWASA. These data represent the entire population for this study; that is, the population encompasses all of the residential water users in the OWASA service area whose households are individually metered. The database obtained from OWASA is called the Population herein; it is used for determining water use patterns for residential households (Objective 1). Additional data that are necessary for Objective 2 (determinants of consumption) include household characteristics and climate information, which need to be merged with the Population data to form a Sample of residential consumers. Individual property data are obtained from Orange County records, and climate data from the North Carolina State Climate Office and OWASA. The collection of the data from these sources and creation of the Sample that is central to this report are discussed in Chapter 2.

For the first objective, the distribution of water use between months (i.e. seasonally), between types of housing units (i.e. single vs. multi-family households), and between locations (i.e. spatially) are studied to determine patterns in water consumption. Summary statistics and preliminary analyses are crucial to the evaluation of residential water use patterns, such as cumulative distribution functions and cross tabulations. Chapter 3 provides a summary and discussion of these results.

Chapter 4 is concerned with identification of the determinants of consumption for OWASA's residential customers, under the second objective for this project. Literature from water use studies is reviewed to identify variables that typically play a role in water consumption, followed by an ordinary least squares multiple regression analysis to assess the significant explanatory variables for residential consumption. The regression analysis is performed on the merged Sample. The effects of the explanatory variables on consumption are measured by their coefficients from the linear regression model.

The third objective of this study concerning passive conservation is addressed using the coefficients of water consumption that are determined from the regression model. It is these water use coefficients that are of interest in this study, not the prediction of future water consumption. As it is assumed that those homes constructed during or after 1994 contain efficient water saving devices, the coefficient on the construction date variable in the regression model is used as an indicator for conservation. This coefficient relates the effect that passive conservation has on water consumption.

From the results of the use patterns and regression analysis, interpretations are made concerning 1) verification of the Technical Memorandums and 2) insight regarding residential water consumption for the OWASA service area. These findings are presented in Chapter 5.

2.0 Database

This chapter deals with the creation of the databases needed to accomplish the objectives in Chapter 1. Water consumption data, called the Population, are collected from OWASA for the analysis of residential water use patterns. These data consist of monthly water use and type of unit (single or multi-family) for individual households over a two year period. To identify the determinants of water use, additional data are gathered from other sources concerning climate information and household characteristics: climate data are from the State Climate Office of North Carolina and OWASA, and household characteristics are from the Land Records Department in Orange County. The climate and household data are then merged with the OWASA consumption data to form the Sample database, which is used for the regression analysis. Each of these data sources and the subsequent cleaning and merging are described in this chapter.

2.1 OWASA Consumption (Population) Data

In December 1998, OWASA began using the Aquilium Customer Service Management System (hereafter referred to as Aquilium). Water consumption information stored electronically at OWASA has been integrated into the Aquilium data management system that is used for billing since that date. The water consumption data in this report contain monthly values from February 1999 to December 2000 for each OWASA customer; altogether the consumption database covers 23 months. This report is limited to only those records that are stored in Aquilium, consumption records prior to February 1999 or after December 2000 are not considered. Hence, this report to a large extent describes current usage.

The data in Aquilium for residential customers has a total of 22,980 records. This water consumption database contains information for:

- Location of the property served
- Town of the property served
- Customer name and ID

- Billing address and telephone number for the customer
- Type of housing unit (single or multi-family)
- Billing cycle
- Total amount and date of bill
- Monthly water consumption (in 1000 gallons) from meter readings

The location of the property served is the service address for the customer. It is the property for which water service is provided. The town of the property served is associated with the service address, and it is either Chapel Hill or Carrboro. Customer name is the person to whom the water bill is sent, and is therefore assumed to be the one responsible for paying the bill. OWASA assigns a unique six-digit number to each customer in their service area. This number does not change for the customer even if the service address is changed (i.e. the customer has moved) or multiple service addresses are associated with that customer (i.e. the customer is paying for more than one property within the OWASA service area). The billing address and telephone number are also included for each customer.

The data in Aquilium for residential customers contains single-family (code 01) and separately metered multi-family (code 02) households. The multi-family residential housing units with master meters are not included in this study, as the focus is on determining water consumption for individual households.

Three billing cycles based on geography are designated by OWASA that determine how the meters are read each month. Customers are currently billed approximately on either the 10th, 20th, or 30th day of each month, which corresponds to one of three billing cycles denoted 500, 600, or 700, respectively. Typically, the meter is read approximately 10 days prior to the billing date. Using the same method used by OWASA's consultants in TM3.2, monthly water use in this study is adjusted so that consumption is normalized for equivalent calendar months for all customers.

It is assumed that among residential customers the monthly billing cycles are evenly distributed. Table 2.1 summarizes the billing cycle information for OWASA that is described here. Water use from the 500 cycle, billed on the 10th of each month, is read at the end of the previous month and is therefore consumed in the preceding month. Water use from the 600 cycle, billed on the 20th of each month, consists of water consumed from one third of the current month and two thirds of the previous month. Water use from the 700 cycle, billed on the 30th of each month, consists of water consumed from two thirds of the current month and one third of the previous month.

Table 2.1 – OWASA Billing Cycle Information

Billing Cycle	**Billing Date**	**Meter Reading**
500	10th of Current Month	30th of Previous Month
600	20th of Current Month	10th of Current Month
700	30th of Current Month	20th of Current Month

Unfortunately, there are several difficulties with this method:

(1) The billing cycle for the same customer sometimes changes from month to month.

(2) The customer may not have received a bill for one month (for example, if they moved or are a new customer).

(3) The billing dates are not precisely on the 10th, 20th, and 30th of each month.

These irregularities are accounted for in converting consumption from the Aquilium database to equivalent monthly consumption needed for this study, as described in Appendix A.

According to OWASA's Annual Report (Kerwin and Pelletier, 2000), the number of customer accounts was 15,560 in 1998, 16,577 in 1999, and 17,763 in 2000; these include residential, UNC, and commercial accounts. According to TM3.1, there were a total of 14,309 residential households (not including master metered multi-family units) in 1998, which means that there were more than 1,250 non-residential accounts. Assuming that there were at least this number of non-residential accounts in subsequent years, the total number of residential accounts for this study is approximately 15,000.

As the Aquilium database for this study contains 22,980 customer records, it is obvious that there is some discrepancy. In order to explain the difference of 8,000 records, the database was examined to identify records for which the residential coding is incorrect and to correct any other obvious errors and inconsistencies.

In some cases, the 01 and 02 residential housing units that distinguish single and multi-family dwellings included university or commercial records; therefore 2,220 of these mislabeled records were deleted, since the concern for this study is only with residential consumption. For this study, the focus is on residential customers who pay their own water bill; hence, records of users where bills were paid by construction companies or realtors were eliminated.

Other records that were eliminated include those with either missing billing or service addresses or those that are not in Chapel Hill or Carrboro (120 records), those with consumption data for either none of the study period (374 records), fewer than twelve months of the study period (3,661 records), total consumption less than 24,000 gallons over the study period (3,442), and those with total consumption greater than 1,000,000 gallons per month (9 records). 165 duplicate customer name and service address records were also eliminated. The total number of records in the cleaned water consumption database is 12,965, which is close to and thus considered to be representative of the entire OWASA residential population of concern in this study. The billing cycle and total amount of bill and date categories that are used to normalized the water consumption data are not included in the final database. A sample of the Population database that is used for analysis of residential water use patterns is included in Appendix B.

2.2 Climate Data

Climate information was received from the State Climate Office of North Carolina, which is affiliated with North Carolina State University (see Appendix C). Data for temperature and precipitation are collected daily in Orange County at the Chapel Hill station located at the Jones Ferry Road Water Treatment Plant. Averages for the mean, minimum, and maximum monthly temperature (measured in degrees F) and monthly precipitation (measured in total inches) were requested from this site for the period January 1999 to December 2000, as daily information was not readily available.

Daily climate information was obtained from OWASA for temperature and precipitation for the period between January - December 2000, which was all the data that were available electronically at the time of this report (Appendix D).

Climate data are used to discern relationships concerning seasonal and monthly variations in water consumption. Precipitation data are also important, as outdoor or summer water use should be somewhat limited when the precipitation is sufficient for irrigation.

2.3 Orange County Data

Property information available from public records describes characteristics of specific households in the Population database. Data on individual Chapel Hill and Carrboro properties are assumed to be time invariant. Although this may not be true for some of the property characteristics (for example, additions to houses are made that cause the house value to increase), it is a reasonable assumption because of the relatively short time frame (two years) of this study.

Parcel information was obtained from the Parcels database at the Orange County Land Records Department, which is a compilation of electronic property data collected from various county offices, including the Land Records Department, Assessor's Office, and Planning Department. Much of the information is purportedly updated annually for all properties by the Assessor's Office. The database contains information on 89 different characteristics for each of the known parcels in Orange County. A summary of the field names contained in the database, descriptions of the fields, and the source of the data is listed in the Orange County Data Dictionary that was developed in December 2000 (Appendix E).

For the Towns of Chapel Hill and Carrboro, the Parcels database contains 21,245 records. Since this database contains some parcels whose status is not considered active (i.e. the property is inactive or exempt from the current year's tax bill from the Assessor's Office), 2,040 records were initially eliminated. Approximately 2,850 records were also deleted for those properties which do not have any buildings on them, and approximately

2,800 records were deleted for building types that are labeled either commercial, an outbuilding (i.e. garage, shed, etc.), or a price insert (i.e. carport, deck, tennis court, etc.).

The resulting information from the Parcels database that is included in this report is listed below, and the categories are subsequently described in further detail. Explanations for any records that were further eliminated while cleaning the data set are also given in this section. The Parcels database contains the following information:

- Name(s) and billing address of the property owner of the parcel
- Description of the parcel location
- City, state, and zip code of the parcel
- Parcel size
- Latitude and longitude coordinates
- Building class
- Assessed value of the land, house, and land and house combined
- Year that the house was built
- Number of rooms in the house
- Number of bathrooms and fixtures

The database includes the name and billing address for the owner of the property (not the address of the property itself). Records were eliminated for parcels that had duplicate billing addresses (as they could not be associated with a specific property) and for those with no billing address (approximately 2,500 records). To obtain consistency with the Population database, the remaining addresses were revised so that the same abbreviations were used for street extensions for all records.

Parcel location is a legal description of the property that is included to help identify some of the property locations, as the property address is not included in the Parcels database. Often this field contains useful information, such as the subdivision name, which is used to estimate construction dates of some of the houses in the Sample.

Parcel size (lot size) is the area of the property in square feet, which is obtained from the digitized maps in the Land Records Department. Latitude and longitude dimensions are measured from the center of the parcel polygon and are in state plane

NAD83 coordinates. NAD83 coordinates are based upon a grid system of zones in a network of geodetic control points known as the North American Datum that were updated in 1983 (Dempsey, 2000).

Building class code represents either single or multi-family homes in the residential sector. Single family homes are designated 1, duplexes designated as 2, triplexes as 3, etc. This study breaks down housing type into two groups: single-family and multi-family residential units. Fewer than 10 percent of the records in the Parcels database contain information for this field; where available, they verify information in the OWASA Population database.

Assessed value (in dollars) of the land, house, and combined total value is an indicator of household wealth and/or income. This research does not involve household surveys from which income information could be obtained; therefore, assessed property value is used as an indicator for the wealth or income of the household, as these data are available for all of the properties in the study area.

The year that the house was built is estimated if the house is very old. Twenty percent of the records in the database contain construction dates for the houses. The number of rooms in the building on the property is included for approximately twenty percent of the sample as well.

The number of bathrooms and fixtures are combined into one field in the Parcels database and are broken down into two separate categories for this report. The number of bathrooms is recorded in increments of half-baths; in other words, a household can have 1.5 bathrooms, which means a full bathroom (including a shower or bathtub) and a half-bath (containing just a toilet and sink). The number of fixtures is recorded for those over the five fixture standard limit. The standard five fixtures that are assumed to be in each household are a water heater, kitchen sink, bathroom sink, toilet, and shower or bathtub. Therefore, the total number of plumbing fixtures in the household is the value recorded in the database plus five. Only about 16 percent of the records contain values for this category.

A sample of the final Parcels database, which has a total of 10,779 records, is attached (see Appendix F).

2.4 OWASA House Construction Date Information

Information was gathered manually from OWASA in order to establish the dates of construction for some houses in the Population database. The OWASA work orders for setting water meters, which are organized by subdivision, were reviewed. The work orders contain information regarding the date that the meter was set for a house and thus helped to determine the approximate construction date of houses within several subdivisions in Chapel Hill and Carrboro. The parcel description field in the Parcels database is used to help match the construction dates of some of the houses in the Sample using subdivision names.

A summary of the data gathered from the OWASA work orders is included in Appendix G and is incorporated into a field in the OWASA database before merging all of the data sets. For the purposes of this study, it was assumed that all houses with meters set on or after July 1994 contained plumbing fixtures that were up to code (low flow), assuming it takes approximately six months to build a house and that all houses that started construction as of January 1994 were meeting the national plumbing code.

2.5 Merging Data

The data sets described above –the Aquilium Population database, the Climate databases, and the Parcels database – were merged using Stata and SAS statistical programs to create one combined database, called the Sample herein. The Population data and climate information were match-merged using the month, as these are both time series data. The resulting data set was then match-merged with the Parcels database using the service and billing addresses, respectively, to obtain the final Sample database used for the regression analysis. This Sample contains 115,303 total observations for 5,321 households, and only includes information for those properties whose addresses matched. Because this merge resulted in the loss of some information, as not all of the records from the individual databases matched, a comparison of the Population (using the

Aquilium database) and the Sample (using the merged database) is conducted in the Chapter 3.

Using the Sample, a new field was added for the house construction date. The two construction date fields, one from the Parcels database and the other from the manually collected OWASA house construction date information, were combined and the 150 mismatched records (i.e. they had different values in the individual databases) were eliminated. The housing type (i.e. single versus multi-family) fields were also matched to create a new combined housing type field with the information from both the Population and Parcels data.

3.0 Residential Water Use: Patterns

This chapter presents a preliminary examination of residential water consumption patterns. First, water use is summarized for the households that comprise the entire Population for this study. Average monthly consumption is then described for the Sample of residential households from the merged database that contains additional information concerning household characteristics. Next, the Population and Sample are compared to ensure that the Sample represents the Population. Finally, seasonal, climatic and household characteristics that affect water use are identified and examined for the Population and Sample.

3.1 Population Consumption

Table 3.1 shows the results of average overall water consumption broken down by household type during the period February 1999 - December 2000 for the 12,965 households that make up the Population.

Table 3.1 – Average Water Consumption for the Population Feb 1999 - Dec 2000

Housing Type	Number of Households	Average Monthly Consumption per Household (gallons)	Standard Deviation (gallons)	Average Consumption (mgd)
Single-family	10,443	6,600	5,670	2.02
Multi-family *	2,522	4,050	3,390	0.28
Total	12,965	6,130	5,420	2.30

* Separately metered units only

There is a significant difference between average monthly water use in single-family (6,600 gallons per household) versus multi-family units (4,050 gallons per household), a difference approximately 40 percent. Average consumptions in million gallons per day (mgd) in Table 3.1 are very similar to those summarized in CH2M-Hill's TM3.1 for 1992 through 1998 (see Table 1.2). Not only the monthly average but also the variation in water consumption, indicated by the standard deviation, is quite different for both household types. For comparison, average consumption over an eight-year period for a study in Denver (Litke and Kauffman, 1993) ranged from 163 to 804 gallons per housing unit per day (approximately 5,000 to 24,000 gallons per household per month), so variation in consumption appears to be typical.

Cumulative distributions are used to describe typical household consumption per month and are helpful to identify outliers. The exceedance value at the 99th percentile is used to remove the outliers for this report. The exceedance values for each month are depicted by the bars in Figure 3.1, which represent the upper limit on the amount of water per month that 99 percent of the customers consume. In July 1999, for example, 99 percent of the households consumed 40,000 gallons of water or less (about 1,300 gallons per day). Note that in year 2000, the 99 percent exceedance values for the winter months of January and February (16,000 and 15,000 gallons, respectively) are significantly lower than for the summer months of June through August (ranging from 29,000 to 36,000 gallons). The average 99th percentile exceedance value for all months, 26,000 gallons per month per household, is used to eliminate outliers from the Population database in this study.

Figure 3.1 – Exceedance Values at the 99th Percentile by Month

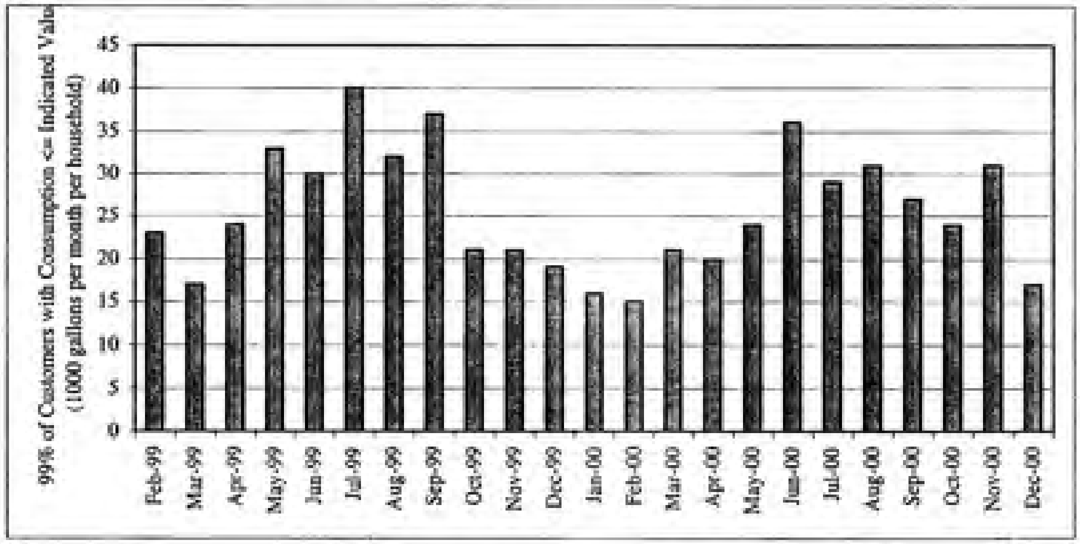


Table 3.2 shows summary statistics for the Population database once the outliers were removed. Average consumption in the cleaned data set (Table 3.2) decreased slightly compared to the raw data in Table 3.1, but the values do not change dramatically;

thus the cleaned Population database is used as the Population for the remainder of this report. The standard deviations in Table 3.2 show the variation in aggregated monthly consumption for each housing type; they are somewhat lower than the standard deviations in Table 3.1 as a result of removing outliers.

Table 3.2 – Average Monthly Water Consumption (gallons per household) by Housing Type for the Cleaned Population Database

	Total		**1999**		**2000**	
Housing Type	**Average**	**Standard Deviation**	**Average**	**Standard Deviation**	**Average**	**Standard Deviation**
Single-family	6,210	4,130	6,330	4,270	6,110	4,000
Multi-family	3,970	2,770	4,000	2,830	3,940	2,720
Total	5,790	4,010	5,890	4,140	5,710	3,890

3.2 Sample Consumption

The Sample that resulted from the merged databases contains approximately 5,300 households. The outliers were eliminated using the exceedance value at the 99^{th} percentile for each year. For 1999, this value was 27,000 gallons per month, and for year 2000, the exceedance value was 25,000 gallons per month. Table 3.3 shows average monthly consumptions and standard deviations for the households in the Sample with the outliers removed; this database is used as the Sample for the remainder of this report.

Table 3.3 – Average Monthly Water Consumption (gallons per household) by Housing Type for the Cleaned Sample Database

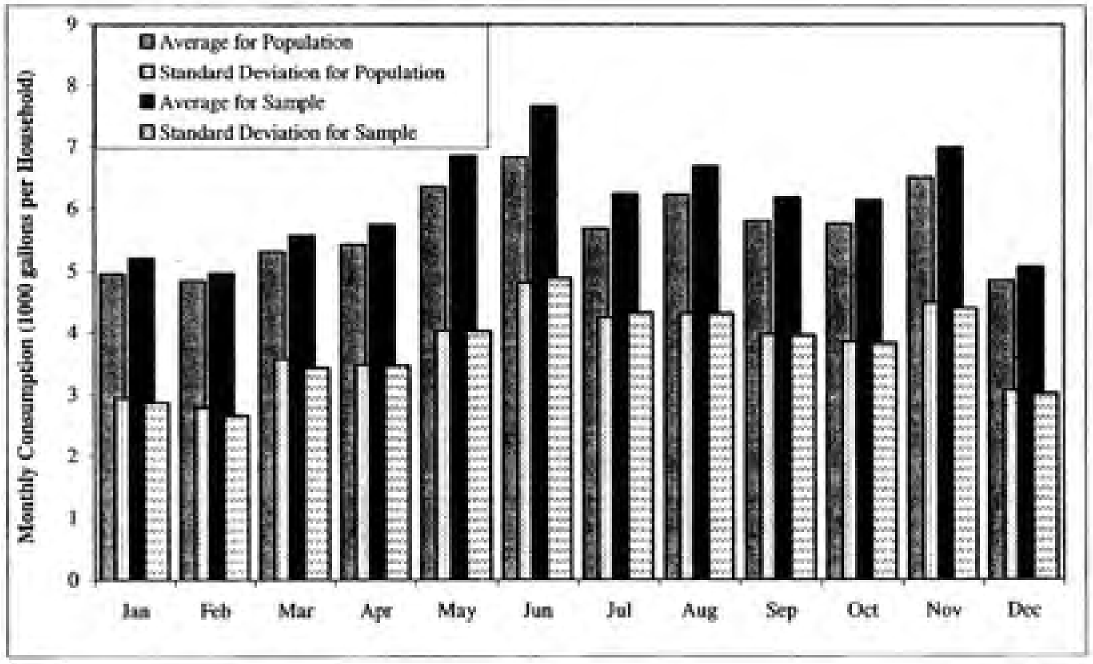
	1999		**2000**	
Housing Type	**Average**	**Standard Deviation**	**Average**	**Standard Deviation**
Single-family	6,570	4,350	6,300	3,930
Multi-family	4,030	3,060	4,000	2,800
Total	6,360	4,320	6,110	3,900

3.3 Comparison of Population and Sample

In order to demonstrate that the Sample is representative of the Population, average consumption patterns, cumulative distribution functions, and spatial distributions are compared for year 2000. This is necessary as the Sample contains household characteristics and climate information that are crucial to the analyses in the remainder of this report for Objectives 2 and 3.

A plot of average consumption for all household types (single and multi-family) and standard deviation by month for year 2000 is shown in Figure 3.2 for the Population and Sample. This plot shows that both average consumption and standard deviation of the Population and Sample month by month agree quite well. For example, average consumption in January is about 5,000 and 5,200 gallons per household for the Population and Sample, respectively, and the corresponding standard deviations are 2,940 and 2,880 gallons per household, respectively. The Population data are included in Appendix H.

Figure 3.2 – Average Monthly Consumption and Standard Deviation for the Cleaned Population and Sample for 2000



For both the Population and Sample, there is a distinct seasonal change in average consumption from approximately 5,000 gallons in December, January, and February to more than 7,000 gallons in June, as well as increasing variability (i.e. standard deviation) during summer months, when outdoor use is high for some households. Two months that do not follow the expected trend, July and November, should be noted. It is anticipated that consumption in July would be similar to that in June and August, but there is a noticeable decrease in water use for July 2000. A similar but reverse situation is seen for November, where the consumption would be expected to be lower (i.e. more like October consumption). Whereas CH2M-Hill (1999) reported peak water use in September, this study found that it occurred in June in year 2000.

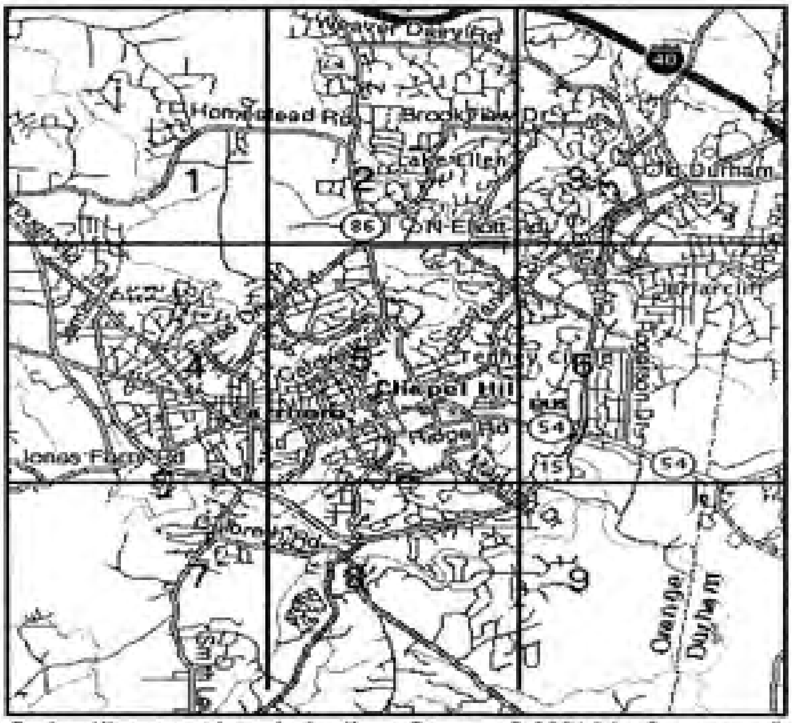
Table 3.4 summarizes water use for the year 2000 using cumulative distributions for the Population and Sample. For example, approximately 80 percent of all households in both the Population and Sample consumed not more than 8,000 gallons per month. It is interesting to note the differences in minimum consumption for single and multi-family units. For instance, approximately 30 percent of all multi-family households use less than or equal to 2,000 gallons per month versus only 11 percent of single-family households. Cumulative distribution functions for water use, including the frequency, cumulative frequency, and cumulative percent for the Population and Sample are included in Appendix I.

Table 3.4 – Cumulative Frequencies (%) for Monthly Water Use (gallons per household) in the Population and Sample for Year 2000 by Housing Type

	All Households		**Single-family**		**Multi-family**	
Water Use	**Population**	**Sample**	**Population**	**Sample**	**Population**	**Sample**
≤ 2,000	14.6	13.1	11.5	11.4	27.9	32.6
≤ 4,000	42.8	39.8	37.5	37.2	66.2	68.7
≤ 6,000	67.0	64.6	62.7	62.6	86.2	86.8
≤ 8,000	81.6	80.3	78.8	79.1	93.7	93.5
≤ 10,000	89.4	88.6	87.8	87.8	96.9	97.0
≤ 15,000	96.8	96.7	96.2	96.5	99.2	99.2
≤ 20,000	99.0	99.0	98.8	98.9	99.8	99.8
≤ 30,000	100	100	100	100	100	100

To further compare the Population and Sample, the spatial distribution of the households is examined. For this study, nine zones of approximately equal area were created for the Chapel Hill and Carrboro area, served by OWASA, as shown in Figure 3.3.

Figure 3.3 – Zones of the OWASA Service Area



Scale: 1" = approximately 1 mile   Source: © 2001 MapQuest.com, Inc.

Table 3.5 shows the percent of households in each of the nine zones for the Sample versus Population for year 2000; with few exceptions, the agreement is quite good, which implies that spatial distribution of households in the Population and Sample is about the same.

Table 3.5 – Percent of Households in Population and Sample by Zone for Year 2000

Zone	*1*	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Population	0.1	7.4	11.1	9.6	35.1	22.1	1.8	10.4	2.4
Sample	1.9	12.6	16.3	9.3	23.1	19.0	1.8	13.8	2.2

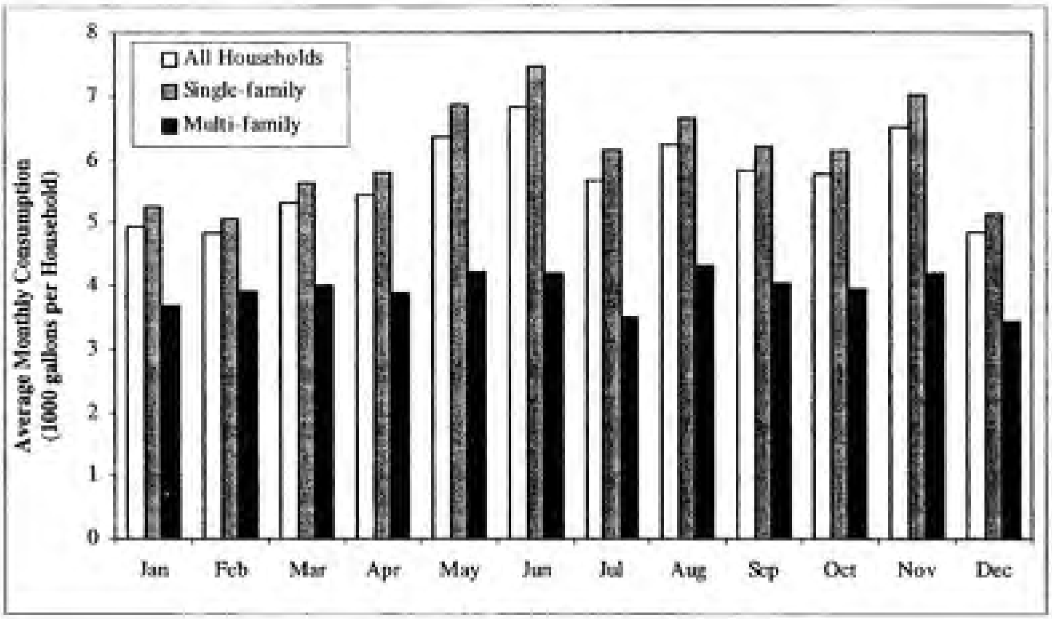
The average monthly consumption and standard deviations in Tables 3.2 and 3.3, for the Population and Sample respectively, the cumulative distribution functions in Table 3.4, and the spatial distribution in Table 3.5 all show that the statistical characteristics are quite similar for the Population and Sample. Therefore, it is concluded that the Sample is representative of the Population, and both are used interchangeably for the analyses in the remainder of this report.

3.4 Seasonal Patterns of Consumption

This section provides a summary of average household consumption by month to assess seasonal variations. Monthly consumption is shown for all households and also broken down into single and multi-family housing units to evaluate seasonal trends. Consumption is also broken down into indoor and outdoor uses, and then compared with climate information to identify associations.

Using the Population, Figure 3.4 shows the average monthly consumption for all households and broken down by housing unit (single and multi-family households) for year 2000. Population data are included in Appendix H. As in Figure 3.2, overall consumption varies by month with a noticeable increase in the summer months. This variation is especially clear for single-family households, as multi-family households do not display as much variability in use between summer and winter seasons. The seasonal peak for both housing types occurred in June with 7,500 gallons used on average in single-family households and 4,200 gallons in multi-family units. The minimum average consumption was in February for single families (5,100 gallons) and December for multi-family households (3,400 gallons). Litke and Kauffman (1993) argue that minimum monthly consumption is a good indicator of indoor water use, as most outdoor uses occur in summer months. Therefore, consumption above 5,100 gallons per month for single-family units or above 3,400 gallons per month for multi-family units appears to constitute outdoor use.

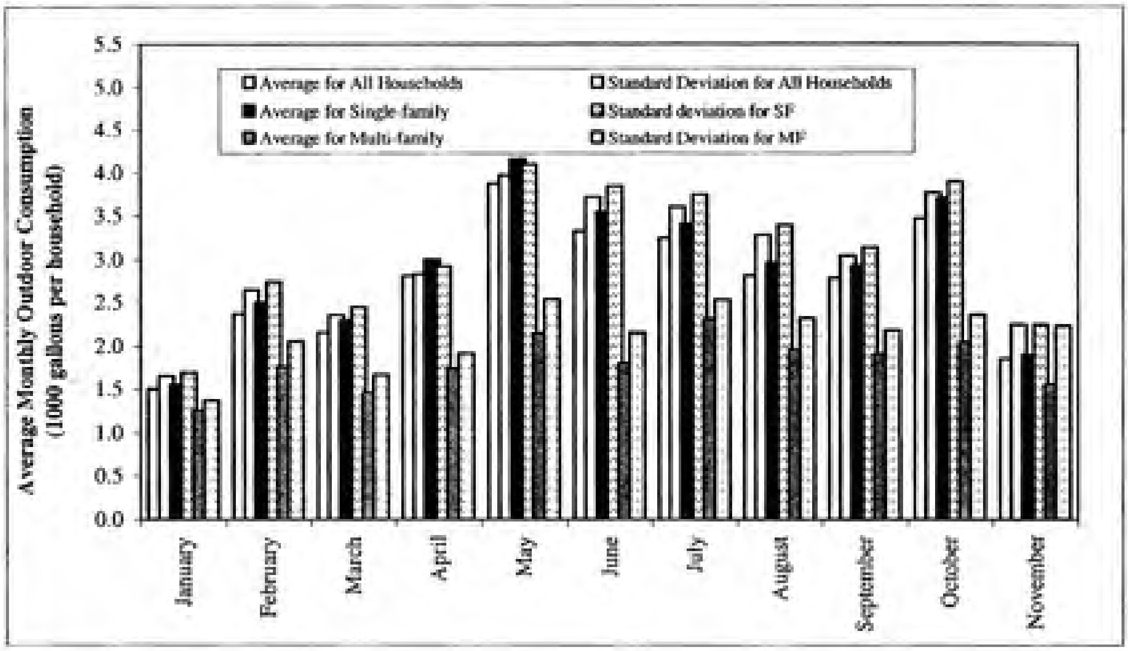
Figure 3.4 – Average Monthly Consumption for Single and Multi-family Households for Year 2000



In order to investigate the amount of indoor versus outdoor water use, February was chosen as the representative month of indoor use for single and multi-family households for the Population in year 2000; any amount over the baseline in February was considered outdoor use for each month. Figure 3.5 shows average outdoor consumption for both single and multi-family units by month; note that February is not included in the chart. Data for outdoor consumption for the Population are included in Appendix H.

Outdoor consumption ranges from 1,600 gallons per household in January to 4,200 gallons per household in June for single family units. The outdoor component makes up approximately 30 percent of total use in winter and almost 60 percent of total use in summer for single-family households. The standard deviation is of the same magnitude as average outdoor consumption for both single and multi-family households. However, outdoor consumption for multi-family households does not vary as much seasonally, ranging from 1,300 gallons per household in January to 2,300 gallons per household in August, almost half of the summer outdoor consumption for single family units. Although outdoor use accounts for approximately 35 to 55 percent of the total use for the multi-family units, which is similar to single family households.

Figure 3.5 - Average Outdoor Monthly Consumption and Standard Deviation for Single and Multi-family Households for 2000



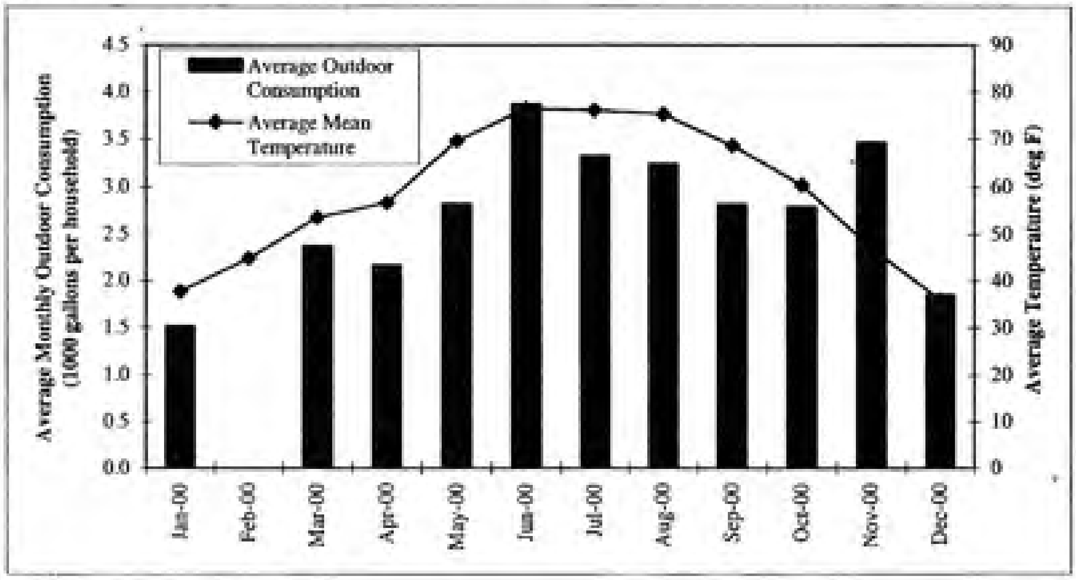
Results of estimated indoor versus outdoor consumption averaged over the year for each housing type are shown in Table 3.6. For single-family households, average monthly outdoor consumption for the year is approximately 48 percent of the total use; for multi-family households, outdoor consumption is approximately 42 percent of the total. This table shows that yearly standard deviations for both housing types are greater than average outdoor consumption, which means that outdoor use is highly variable.

Table 3.6 – Estimated Outdoor Monthly Consumption for Year 2000

Household Type	Average Monthly Outdoor Consumption (gallons/household)	Standard Deviation for Outdoor Consumption
Single-family	2,910	3,110
Multi-family	1,660	2,120
Total	2,750	3,010

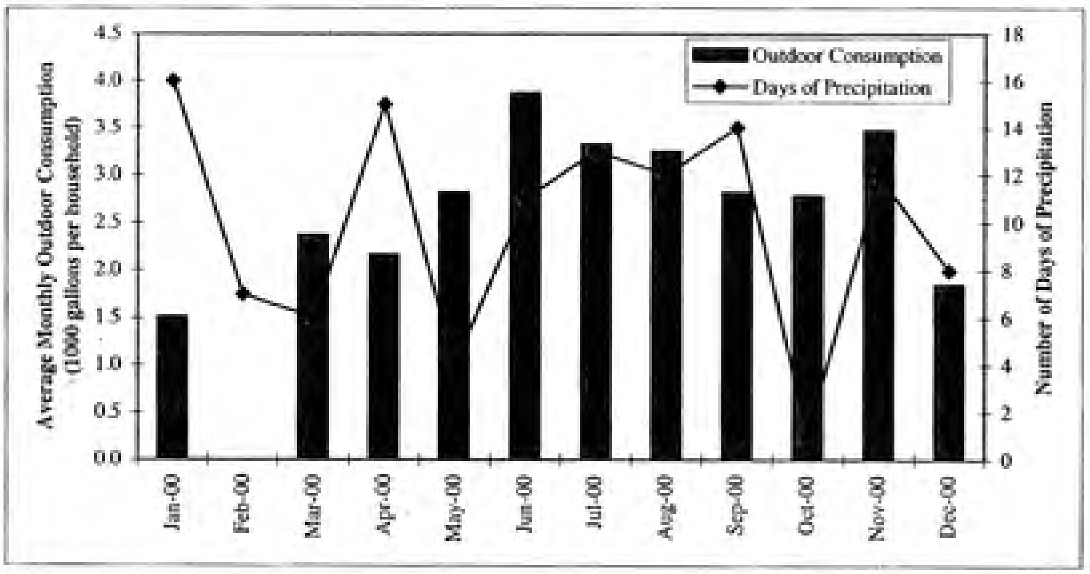
It is expected that outdoor consumption is related to both the temperature and amount of precipitation received per month, which both vary seasonally. A USGS report in Middle Tennessee found that weather (temperature and rainfall) was significant in determining water use patterns in the basin studied (Hutson, 1993). Average monthly temperature values are lowest in January and December (about 50 degrees F) during which time outdoor consumption is minimal. Highest mean temperatures range from 75 to 80 degrees F in June, July, and August. Figure 3.6 shows average outdoor consumption versus mean monthly temperature for each month in 2000. The outdoor consumption does appear to follow the average temperature, with the exception of both July and November.

Figure 3.6 – Outdoor Consumption versus Mean Temperature for Year 2000



Local precipitation is greatest in the winter and early spring and lower in summer and fall. Daily climate information is used in this report, as outdoor activities are likely dependent on climate trends over the course of several consecutive days not just aggregated over a monthly period. The number of days of precipitation is plotted versus the monthly outdoor consumption in Figure 3.7 for the period January through December 2000. It is expected that outdoor consumption and precipitation would have an inverse relationship. It is difficult to interpret the Figure 3.7 as the information only includes the number of days during which any precipitation occurred in the current month; it does not take into consideration the amount of precipitation that month, if the days were consecutive, or the amount and patterns of precipitation from the previous month.

Figure 3.7– Outdoor Consumption versus the Number of Days of Precipitation per Month for Year 2000



3.5 Comparison with End Use Studies

In order to compare the results from this study regarding consumption patterns and indoor versus outdoor use, a literature review of end use studies was conducted. In 1994, an end use study was conducted in 16 sample residential households in Boulder, Colorado (DeOreo et al., 1996) using flow trace analysis to assess water use patterns for specific end uses. Summer outdoor use (from June to September) was found to encompass almost 78 percent of the total water demand, as compared to approximately 60 percent in this study. The Boulder study was a precursor to the much larger American Water Works Association Research Foundation (AWWARF) study conducted across the county (Mayer et al., 1999).

The AWWARF study entitled "Residential End Uses of Water" is one of the most comprehensive water use studies conducted to date. Residential end uses, such as toilets, showers, clothes washers, and irrigation, were monitored during the study using data loggers to determine water consumption. Fourteen cities, comprising twelve study sites, participated in the AWWARF residential water use study. Two cities in Arizona and two in Ontario were combined to form a single study site in each location. Approximately 1,000 randomly selected households participated in the household survey, and 125 to 150 individual households were monitored using data loggers within each study site. Although the various sites were skewed towards the West and Southwestern regions of the United States, with four locations in southern California, the end uses in the specific sites of the study were surprisingly similar, implying that end uses can perhaps be reasonably extrapolated to areas where such intensive water use studies have not been conducted (i.e. our study area in the Southeast).

For the 12 combined sites, an average of 146,100 gallons of water was consumed per household per year (approximately 12,175 gallons per household per month), with 58 percent of annual use for outdoor purposes, which was strongly influenced by season. As in other water use studies, outdoor use was determined by assuming that usage during the minimum month contains no outdoor component. The monthly consumption of approximately 12,000 gallons per household is twice that of the consumption in the OWASA service area. The percent of annual outdoor use of 58 percent in the AWWARF study is about 10 percent higher, compared to annual outdoor use of 42 to 48 percent in our study for single and multi-family households, respectively.

3.6 Patterns of Consumption versus Household Characteristics

This section examines associations between average monthly consumption and household characteristics. Variables investigated include household and property characteristics, specifically assessed value of the house, lot size, number of bathrooms, and construction date of the house. House value and lot size contain data for all of the households in the Sample, but the number of bathrooms and construction date information are incomplete and have data for only 959 and 1,229 households, respectively, covering only about 20 percent of the Sample for these variables. The small sample size affects the confidence that can be placed in the findings.

Tables and cross tabulations broken down by category are used to analyze general patterns between average consumption and household characteristics for year 2000. All of the tables and cross tabulations are for both single and multi-family households (i.e. pooled data).

Table 3.7 shows the association between average monthly household consumption and assessed value of the house. A clear trend of increasing water use per household versus increasing house value is seen, with average minimum consumption of approximately 4,400 gallons for those homes that are valued at less than or equal to $100,000 and an average maximum consumption of approximately 11,000 gallons for homes that are valued at more than $500,000. Hence, consumption appears to increase monotonically with assessed house value. Note, however, that the number of data points (i.e. households) is small for the more expensive houses, which affects the confidence that can be placed in those results.

Table 3.7 – Average Monthly Water Consumption versus Assessed House Value

Assessed House Value	Average Consumption (gallons/month/household)	Number of Households
≤ $100,000	4,380	1,070
$100 - 150,000	5,440	1,240
$150 - 200,000	6,070	1,065
$200 – 250,000	6,950	848
$250 – 300,000	7,650	445
$300 – 400,000	8,430	308
$400 – 500,000	9,660	105
> $500,000	10,950	45

Table 3.8 shows the association between average monthly household consumption and lot size. The majority of properties (68 percent) have lots that are one-half acre or less in size. Similar to the previous results, average consumption increases monotically with size. However, consumption tapers off for houses with lots larger than about 0.25 acre, i.e. the marginal increase in average consumption decreases as lot size increases above 0.25 acre.

Table 3.8 – Average Monthly Water Consumption versus Lot Size

Lot Size (acre)	Average Consumption (gallons/month/household)	Number of Households
0.125	3,970	570
0.125 – 0.25	5,690	860
0.25 – 0.5	6,210	2,050
0.5 - 1	6,880	1,275
> 1	7,050	390

A cross tabulation is used to look at average monthly consumption combining house value and lot size, as shown in Table 3.9. The lowest average consumption of 3,600 gallons per household is for homes valued at $100,000 or less and with lot sizes less than or equal to 0.125 acre. Consumption ranges from approximately 3,600 to 5,300 gallons per household (HH) for lower valued homes (less than $150,000) with lots less than 0.25 acre. Homes valued over $400,000 with lots of at least one-half acre have monthly consumption that ranges from an average of approximately 9,500 to 12,900 gallons per household, which is about three times the consumption of lower valued homes with small lots.

Table 3.9 – Average Monthly Water Consumption (gallons per household) vs. Lot Size and Assessed House Value

		Assessed House Value ($1000)							
Lot Size (acre)	# of HHs	≤ $100	$100 - 150	$150 - 200	$200 - 250	$250 - 300	$300 - 400	$400 - 500	>$500
0.125	570	3,590	4,210	3,870	5,210	4,330	-	-	-
0.125-0.25	860	4,200	5,270	6,120	6,690	7,050	7,960	6,900	-
0.25-0.5	2,050	4,680	5,790	6,380	7,150	7,800	8,050	10,170	12,880
0.5-1	1,275	5,050	5,710	6,260	7,220	7,900	8,730	9,670	10,720
> 1	390	4,840	5,400	6,100	6,940	7,510	8,310	9,530	10,870
Number of HHs		1,070	1,240	1,065	848	445	308	105	45

Table 3.10 shows the association between average monthly household consumption and the number of bathrooms. As seen with other variables, average monthly consumption increases monotonically with the number of bathrooms, ranging from approximately 3,800 gallons per household for one bathroom up to approximately 7,400 gallons per household for four bathrooms. Although there are households with seven bathrooms in the Sample, only single-family households have more than three bathrooms, and of those single-family homes very few have more than 3.5 bathrooms. Since there are so few households (is some cases only one) with more than three bathrooms, there is very little confidence in the results for those households in this range and therefore houses with more than four bathrooms are not included in this report. Although there are not many households in the Sample for this variable, there is confidence in the preliminary results showing the steady increase in consumption versus the number of bathrooms.

Table 3.10 – Average Monthly Water Consumption versus Number of Bathrooms

Number of Bathrooms	Average Consumption (gallons/month/household)	Number of Households
1	3,770	134
1.5	5,000	68
2	5,080	300
2.5	6,020	246
3	6,660	103
3.5	7,780	50
4	7,350	18

Table 3.11 shows the pattern of monthly consumption in terms of assessed house value and the number of bathrooms. There is an increase in consumption from houses with assessed value lower than \$150,000 and less than two bathrooms (less than 5,000 gallons per household) to those houses with assessed value over \$250,000 with more than 2.5 bathrooms (more than 7,000 gallons per household). The trends for an increasing number of bathrooms for each house value are not as clear, as they do not steadily

increase down the columns for all house values. For the highest house values and number of bathrooms, this is most likely due to the small number of households in the Sample at these points, but it also may be related to the fact that there are multiple variables affecting average monthly consumption that make it difficult to interpret the tables.

Table 3.11 – Average Monthly Water Consumption (gallons per household) for Number of Bathrooms and Assessed House Value

		Assessed House Value ($1000)							
Number of Bathrooms	**# of HHs**	≤ $100	$100 - 150	$150 - 200	$200 - 250	$250 - 300	$300 - 400	$400 - 500	>$500
1	134	3,670	4,530	8,170	5,830	-	-	-	-
1.5	68	4,980	4,960	5,610	-	-	-	-	-
2	300	4,480	5,100	5,920	7,780	8,480	-	-	-
2.5	246	3,950	5,530	5,760	6,870	7,350	8,490	5,080	-
3	103	-	5,380	6,370	7,480	7,850	7,430	10,500	-
3.5	50	-	5,080	6,410	7,300	8,900	7,310	11,570	-
4	18	-	10,360	5,920	6,530	8,380	6,740	6,850	8,130
# of HHs		300	230	175	85	50	30	7	2

Table 3.12 shows the association between average monthly household consumption and the construction dates of houses. Recall that 1994 was the date when low flow toilets and showerheads were required in new homes. Average consumption ranges from 5,000 gallons per household in 1950 - 1960 up to approximately 6,800 gallons per household in 1996 - 1998. After 1998, there is a decrease in consumption from approximately 6,800 gallons per household to approximately 5,800 gallons per household between 1998 and 2000, but the sample size is small. For the two periods before and after the 1994 regulation (1992-1994 and 1994-1996), there is actually an increase in average monthly consumption, which is possibly due to the small number of households with construction dates in the Sample, or the likelihood that monthly consumption is affected by more than just construction date and hence is not captured in the tables.

Table 3.12 – Average Monthly Water Consumption versus Construction Date

Construction Date	Average Consumption (gallons/month/household)	Number of Households
1950 – 1960	5,000	110
1960 – 1970	5,790	195
1970 – 1980	5,580	160
1980 – 1990	5,560	305
1990 – 1992	6,480	75
1992 – 1994	6,370	60
1994 – 1996	6,460	65
1996 – 1998	6,760	105
1998 – 2000	5,840	30

In order to further examine the effects of the construction date, Table 3.13 shows a cross tabulation of consumption with construction date and the assessed house value.

Table 3.13 – Average Monthly Water Consumption (gallons per household) for Construction Date and Assessed House Value

		Assessed House Value ($1000)							
Construction Date	# of HHs	≤ $100	$100 - 150	$150 - 200	$200 - 250	$250 - 300	$300 - 400	$400 - 500	>$500
1950 – 1960	110	3,900	5,790	7,710	8,150	14,640	2,750	10,500	-
1960 – 1970	195	4,780	5,710	6,170	7,010	8,790	4,000	17,900	-
1970 – 1980	160	4,680	5,340	6,340	8,550	7,540	6,950	-	-
1980 – 1990	305	3,710	4,930	5,780	7,160	7,970	8,560	11,130	8,130
1990 – 1992	75	3,970	6,220	5,840	6,680	8,360	8,600	12,050	-
1992 – 1994	60	3,330	5,120	5,920	6,140	8,060	7,690	6,960	-
1994 – 1996	65	4,550	6,060	5,120	7,260	7,460	7,710	12,950	11,370
1996 – 1998	105	6,010	5,790	5,900	6,910	7,770	7,650	3,580	13,250
1998 – 2000	30	5,380	5,900	5,630	5,970	6,380	7,910	-	-
Number of HHs		1,070	1,250	1,070	850	450	305	105	45

This cross tabulation is examined to see if controlling for one of the variables leads to a clearer pattern with the construction date. Only two of the columns show a decrease in average consumption for period after 1994. For example, houses valued between $150,000 and $200,000 reveal a decrease in average monthly consumption from approximately 5,900 to 5,100 gallons per household. For most of Table 3.13, the associations are unclear.

Table 3.14 shows the association between the construction date and the assessed value of the house. The percent of houses with an assessed value of less than or equal to $150,000 is compared to the construction date to determine if newer houses are more expensive. There is a noticeable decrease in the percent of houses that fall into the lower categories for assessed value after 1990, which shows that there are confounding effects from other variables that cause the effect of construction date on average monthly consumption to be unclear.

Table 3.14 – Construction Date versus the Percent of Households with Value <= $150,000

Construction Date	Percent of Households with Value <= $150,000	Number of Households
1950-1960	87	108
1960-1970	65	197
1970-1980	66	163
1980-1990	54	308
1990-1992	30	75
1992-1994	23	60
1994-1996	30	65
1996-1998	28	104
1998-2000	38	34

Difficulty in discerning clear patterns is likely due to the fact that the cross tabulations do not give a complete picture, as only one or two variables are analyzed at one time. Other factors involved in water consumption, such as the lot size or even climatic trends, make it difficult to interpret these results, which is a main reason why cross tabulations are only done for initial screening to get a sense of relevant patterns. Therefore, regression analysis is needed so that all the relevant variables that contribute to monthly residential water consumption can be included.

In summary, some of the key results from the preliminary results in this chapter are the following:

- Single family units consume approximately 60 percent more than multi-family households.
- Approximately 30 percent of all multi-family households, versus only 11 percent of single family households, use a maximum of 2,000 gallons per month per household.
- There is a distinct seasonal association of monthly consumption for single family units, with the highest use of 7,500 gallons/month/household (gal/mo/HH) in summer.
- Outdoor monthly consumption also shows a strong association by month, with summer use approximately 4,000 gal/mo/HH for single family and 2,300 gal/mo/HH for multi-family units.
- Outdoor consumption accounts for approximately 55-60 percent of the total use in the summer for all households.
- Average monthly consumption monotonically increases with assessed house value from approximately 4,000 to 11,000 gal/mo/HH for the lowest to highest valued homes.
- Lot size also shows a monotonically increasing association with consumption, with diminishing marginal increases with larger lot sizes (more than 0.25 acre).
- The association between the number of bathrooms and average monthly consumption monotonically increases from 3,770 gal/mo/HH with one bathroom to 7,350 gal/mo/HH with 4 bathrooms.

- Both lot size and the number of bathrooms are positively related to the assessed value of the house.
- Construction date of the house does not show a clear association with average monthly consumption, even when in association with the assessed value of the house. There is a pattern of more expensive houses being constructed since 1990, so there appears to be confounding variables associated with construction date and average monthly consumption.

4.0 Residential Water Use: Regression Analysis

Preliminary results based on summary statistics, consumption tables, and cross tabulations in Chapter 3 show the need to control for the interactions among variables in order to discern patterns. This chapter presents a regression model for the OWASA service area. Background information from residential water use studies and patterns described in Chapter 3 provide a basis for proposing explanatory variables in regression models.

The objective of the statistical regression analysis is to identify the determinants of household water consumption. A multivariate model is used to describe water use in terms of variables that affect consumption. In a USGS study, a linear relationship was found between quantity of water and various housing variables (Hutson, 1993); hence, the model in this study is a linear additive model.

4.1 Residential Water Consumption Studies

Models in the literature for residential consumption are reviewed in this section to help provide a basis for the specific variables to include in the regression analysis of OWASA data.

One of the studies relevant to this report was conducted by CH2M-Hill and PMCL in 1999 for OWASA. CH2M-Hill and PMCL developed a linear regression model in Technical Memorandum 3.2 (TM3.2) to gauge the relationship between water use and seasonal/climate variation for the OWASA service area. A log model with dummy variables was fit to the data. Log models are common in the field due to the log-normal distribution of water consumption. In much of the literature (CH2M-Hill and PMCL, 1999; Nieswiadomy, 1992), the dependent variable (water use) and independent variables (maximum temperature, precipitation, house value, etc.) are converted to their natural log form and dummy variables are included for years, seasons and months.

4.1.1 Institute for Water Resources - Municipal and Industrial Needs

The models in TM3.2 were generated using the Institute for Water Resources - Municipal and Industrial Needs (IWR-MAIN), a commercial water demand management software package that was first created in the 1960's and has been developed by Planning and Management Consultants, Ltd since the early 1980's (PMCL, 1998). Although IWR-MAIN is typically used as a predictive tool, this is not always the case. For example, in a USGS published report in Middle Tennessee (Hutson, 1993), the IWR-MAIN system was used "primarily to test assumptions and the effects that various assumptions would have on water use in the basin rather than as a predictive tool to generate absolute values showing future water use." Therefore, the IWR-MAIN model is discussed briefly in this section to show its underlying rationale.

Socioeconomic, climate, and pricing factors are included in the IWR-MAIN system to model the water demand for each sector (i.e. single-family residential, commercial, etc.) in terms of the number of users (i.e. housing units, employees, etc.) and the average water use per household or employee. Some of the socioeconomic parameters used in the model include: number of residences, number of persons per household, housing density, household income, resident population, rate structures, total seasonal rainfall, and maximum daily temperature.

4.1.2 USGS Denver Study

A USGS and Denver Water Department study in Denver, Colorado, was reviewed to identify some of the explanatory variables that are used in regression models for residential water use (Litke and Kauffman,1993). Litke and Kauffman found that a previous analysis of residential water use data, performed by the U.S. Army Corps in 1986, estimated use based on three main categories of explanatory variables: weather, size, and affluence variables. Weather variables contribute to the amount of water used for outdoor purposes and include climatic data such as temperature and precipitation. Explanatory variables such as number of people per household and number of bathrooms are size variables that affect inside water use, whereas lot size affects outdoor use. Depending on the pricing system, household income (or a surrogate, such as the value of the house or property) can influence water use, as it affects how much water the household can afford.

For the Denver study, an age factor was introduced as a surrogate for the number of people at home during the day. The factor estimated the number of people in the household at home during the day (i.e. could use water during the day) as those under 18 and those over 65 years old. Regression analysis of lot size on lawn size yielded a linear relation: Lawn Size (sqft) = 0.6 * Lot Size (sqft) – 500 sqft. The authors noted that a power relation might be more appropriate, although the linear equation fits the data well.

Summer water use rates were consistently larger except during rainfall events or drops in temperature. As in most water use studies, winter use is estimated as roughly equivalent to inside water use for the study.

In the USGS Denver study, base water use correlates best with the number of people per housing unit. The age-factor variable did not improve the base water use prediction. For seasonal water use, the explanatory variables that were selected were lot size and billing type. The regression analyses appear to have been conducted in a step-wise fashion, however; the results are not reported for the entire set of explanatory variables, and thus are not considered to be completely reliable, but can only be used as a guide for this technical report.

4.2 Determinants of Water Consumption

The literature review provides a basis for selecting explanatory variables to be included in the OWASA consumption model. The data used for this analysis contain consumption information, household characteristics, and climate records that pertain to the same households over time for a sample of the population. This type of data is called panel or longitudinal data; this is versus independently pooled cross-sectional data, where a random sample is chosen for each time period. Panel data are commonly used to view the unobserved factors affecting the dependent variable - those that are constant and those vary over time (Wooldridge, 2000). In this study, the water consumption data and climate information vary over time, while the household characteristics remain constant over time.

The variables available that are included in the regression model in this study to explain monthly water consumption are: assessed house value, number of bathrooms, property area, construction date of the house, average monthly temperature, number of days of precipitation per month, type of housing unit, and months. These explanatory variables and their anticipated effect on monthly consumption are described further in this section.

Assessed house value and the number of bathrooms are positively correlated with water consumption, as seen from the results in the previous chapter. Property area also has a positive effect on water consumption, as larger lot sizes often translate into more area to be irrigated.

The year that the house was constructed should affect water use due to the regulation and implementation of water saving devices that went into effect in 1994, although this relationship was not clear from the results in Chapter 3. Houses built after this date are required to contain low-flow toilets and showerheads, which may result in a water savings within the household and therefore should have a negative effect on water consumption. Construction date in this regression model is a dummy variable, indicating whether or not the house was constructed before or after 1994. This date is used to as an indicator to determine whether or not households passively conserve water due to the national plumbing standards. As the exact date that the plumbing code was enforced locally is unknown, the date enacted for the federal regulations is assumed for this study.

Average monthly temperature appears to be positively correlated with monthly consumption, as both temperature and consumption follow a similar seasonal pattern. The number of days of precipitation per month is expected to be negative related to consumption, although this is not clear from the preliminary results in Chapter 3. The unclear associations are most likely due to the fact that the precipitation variable needs to include a lag for the previous month, as well as the magnitude and daily patterns of example, successive error terms are related to an excluded variable that tends to change over time (Boardman et al., 1996). The data were tested for problems with multicollinearity, heteroskedasticity and autocorrelation in order to ensure that the assumptions underlying ordinary least squares regression were met (see Appendix J).

Multicollinearity was checked by examining the pairwise correlations of independent variables (for pairwise multicollinearity) and the estimated parameters (for overall multicollinearity), and by calculating the variance inflation factor (VIF) associated with each of the independent variables. The VIF is the ratio of the actual variance of the parameter to what the variance would have been if that variable were uncorrelated with all the other variables.

The pairwise correlations (Appendix J) show that there is somewhat of a multicollinearity problem with several variables, most notably the number of bathrooms and assessed house value. The VIF analysis found that the average temperature was highly correlated with many of the variables, as were several of the months, which is to be expected, as there is a distinct seasonal trend associated with monthly temperature. Assessed house value also appeared to have some collinearity problems in the VIF test.

To correct for multicollinearity, often an interaction term is added to the model to avoid specification bias. However, for this analysis since the assessed value of the house is strongly correlated with the number of bathrooms, only the assessed house value variable is used in the model. Because the results from Chapter 3 show that lot size is also associated with the assessed house value, it is likely that the house value can be included in the model alone and achieve similar results.

To check for heteroskedasticity, the squared residuals from the model were plotted against several of the independent variables and White and Park tests were also conducted (see Appendix J). In some cases, heteroskedasticity can be a problem with outliers, although in this report any obvious outliers were removed previously from the data. More often, heteroskedasticity can be explained for some variables. For example, as seen in Chapter 3, houses with low assessed value typically have low water use. As the assessed house value increases, water use has potential to increase but may also remain low; hence there is a larger variability as house value increases.

The residual plots showed some potential heteroskedasticity with property area, the number of bathrooms, assessed house value, and average monthly temperature. The White test confirmed possible problems with the number of bathrooms, assessed house value, and average monthly temperature, and the Park test yielded similar results for the number of bathrooms and average monthly temperature. However, results from both the White and Park tests show that heteroskedasticity does not appear to be a major problem.

Autocorrelation, a problem encountered when errors from one period are correlated with another period, was investigated by looking at the plots of the residuals over time (see Appendix J). From the plots by month, there does not appear to be any clear positive or negative autocorrelation as the residuals are spread evenly around the origin and show no grouping or pattern. Therefore, autocorrelation does not seem to be a problem in this model.

The regression model is shown in Equations 4.1 with monthly consumption regressed on household, climate and seasonal variables for the Sample.

Equation 4.1 – Regression Model of Monthly Consumption

Monthly Consumption = $\beta_0 + \beta_1$* Assessed value of house + β_2* Type of dwelling + β_3* Construction date + β_4* Average Temperature + β_5* Number of Days of Precipitation + β_6* January+ β_7* March + β_8* April + β_9* May + β_{10}* June + β_{11}* July + β_{12}* August + β_{13}* September + β_{14}* October + β_{15}* November + β_{16}* December + ε

Where, β_0 = intercept
$\beta_1 \ldots \beta_{16}$ = coefficients of monthly water consumption
ε = error term for the model

4.4 Regression Analysis Results

The regression was run on the Sample for the year 2000. Table 4.2 shows the results of the analysis. The effect of each of the variables on water consumption is listed with the standard error and significance.

Table 4.2 – Results from Regression Analysis of Residential Water Consumption for Year 2000

	Coefficient β	**Standard Error**	**Significance**
Assessed house value ($1000)	0.021***	0.0008	0.000
Type of unit	- 1.162***	0.3121	0.000
Construction date	- 0.498***	0.1602	0.002
Average temperature	0.020***	0.0046	0.000
Number of days of precipitation	0.041***	0.0111	0.000
Month Dummy Variables			
March	0.470***	0.1474	0.001
April	0.488***	0.1311	0.000
May	2.162***	0.2180	0.000
June	3.565***	0.2065	0.000
July	1.366***	0.1991	0.000
August	1.585***	0.1986	0.000
September	1.024***	0.1689	0.000
October	1.656***	0.2068	0.000
November	2.546***	0.1101	0.000
December	0.352***	0.1042	0.001

Notes: There were 2,087 households and 24,628 observations. $R^2 = 0.28$.
*** Statistically significant at the 1% level.

Statistical significance is indicated by using the t-statistic, which is the ratio of the estimated variable coefficient to its standard error, $t = \beta/se$. For a normal distribution with a large (>120) sample size, if the absolute value of the t-statistic is greater than 1.96, the parameter is statistically significant at the five percent level. The t-statistic tests the hypothesis that the explanatory variable has no effect on the dependent variable. For example, to test if the type of housing unit is significant in the model (Table 4.2), the null hypothesis states that the type of housing unit has no effect on monthly water consumption. The t-statistic for the housing unit parameter, $|t| = |-1.162/0.3121| \doteq 3.72$, is larger than 1.96 and thus the parameter is significant at the 5 percent level; in fact, the housing variable is significant at the one percent level.

Table 4.2 shows the significance of each variable using asterisks after the coefficients. Note that all of the variables in the model are statistically significant at the one percent or 0.01 level, and therefore are the key contributing variables that affect monthly consumption.

From the results on Table 4.2, interpretations can be made for each variable using the effect of the coefficient on average consumption in 1,000 gallons per month per household, holding all else constant. From the model, the effect of each variable is described as follows:

- For every $1000 increase in assessed house value, average consumption increase by 21 gallons per month per household. For instance, a house that is valued at $200,000 uses 2,100 gallons per month per household more than a $100,000 house.
- Multi-family households use 1,162 gallons per month per household less than a single-family unit on average.
- A house constructed after 1994 uses approximately 500 gallons per household less water than a house constructed before 1994.
- For every one degree increase in temperature, average consumption increases by 20 gallons per month per household. For example, for a change from 50 to 70 degrees, average consumption increases by 400 gallons per month per household.
- With every additional day of precipitation per month, average consumption increases by 41 gallons per month per household, which is not the expected result, but is likely due to problems with the variable that is used for precipitation as previously discussed.

The regression analysis can also be used to calculate monthly consumption under various scenarios, although the objective in this report is to understand what drives consumption, not to make predictions. Table 4.3 shows consumption for average single and multi-family households constructed before and after 1994, using mean values for variables from Table 4.1. The mean values are used in this report to represent a typical household with an assessed house value of $178,000, and an average of ten days of precipitation per month. Average monthly temperatures of 48 and 76 degrees F are used for February (the baseline) and June, respectively.

Table 4.3 –Average Consumption (gallons per month per household)

	Single-family unit		**Multi-family unit**	
Month	Constructed < 1994	Constructed ≥ 1994	Constructed < 1994	Constructed ≥ 1994
February	5,010	4,510	3,850	3,350
June	9,150	8,650	7,980	7,480

As shown on Table 4.3, for example, average consumption for a single-family household constructed before 1994 in winter (February) is 5,010 gallons per household versus 9,150 gallons per household in summer (June). Table 4.3 illustrates the 500 gallons per month per household decrease in consumption for those houses constructed after 1994.

5.0 Discussion

This chapter summarizes and discusses findings, comments on some of the problems with the study, and proposes recommendations for further work.

5.1 Seasonal Patterns

A main focus of seasonal patterns is outdoor consumption. Single-family units have more variation in monthly consumption than multi-family households, and comprise the larger portion of overall outdoor consumption. To get a better idea of how outdoor consumption varies between single and multi-family households by season, a cumulative distribution function was created. Table 5.1 shows the results by cumulative percent for monthly outdoor consumption in the summer versus winter for both types of households. The months of May through September are called "summer," and "winter" months are October through April.

Table 5.1 – Cumulative Percent of Households (%) for Summer versus Winter Outdoor Consumption (in gallons per month per household)

	Summer		**Winter**	
Outdoor Consumption	**Single-family**	**Multi-family**	**Single-family**	**Multi-family**
≤ 500	8	17	20	27
≤ 1,000	29	51	55	68
≤ 1,500	35	59	63	75
≤ 2,000	48	76	78	86
≤ 2,500	52	79	81	88
≤ 3,000	61	85	88	92
≤ 3,500	63	87	89	93
≤ 4,000	70	90	92	95
≤ 6,000	81	95	97	97
≤ 8,000	88	97	98	98
≤ 10,000	92	98	99	99

There is a noticeable difference in monthly consumption between both the type of housing unit and the season. In the summer, approximately 50 percent of the single-family households have monthly outdoor consumption less than or equal to 2,500 gallons per household, versus 1,000 gallons per household for the same percentage of multi-family households. The difference is much smaller in the winter when median outdoor consumption is 900 and 750 gallons per month per household for single and multi-family units, respectively.

The amount of outdoor use is important for OWASA, as they have proposed seasonal pricing as an incentive to reduce consumption in summer months. It is assumed that a reduction in household consumption can be achieved by charging higher prices. Appendix K describes the method and calculations for increasing summer pricing based on the amount of reduction desired.

For example, in year 2000 average outdoor consumption was 3,200 gallons per month per household and average total consumption was 6,190 gallons per month per household in summer. If OWASA wanted to reduce consumption by 500 gallons per month per household in summer, corresponding to an 8 percent decrease, they would have to charge 12 to 27 percent more in summer months (i.e. \$3.23 to \$3.68 per 1,000 gallons), depending on the price elasticity of demand for the customers in Chapel Hill and Carrboro. Price elasticity for water typically ranges from -0.3 to -0.7 in the literature reviewed (see Appendix K).

5.2 Determinants of Consumption

Variables affecting monthly consumption in the regression analysis include the assessed value of the house, construction date, type of housing unit, average monthly temperature, and the number of days of precipitation per month, as well as dummy variables for months. All of the variables in the model were highly significant; however the R^2 value for the model was low (0.28). Therefore, the results should only be used for understanding the effects of variables on monthly consumption and not for making predictions about future use.

The effect of each variable on monthly consumption was as expected except for precipitation. Using the number of days of precipitation per month as the explanatory variable was most likely not sufficient to capture the precipitation effect.

5.3 Passive Conservation

Whereas seasonal pricing targets outdoor consumption, passive conservation focuses on indoor use. For passive conservation, it is expected that all new homes constructed during or after 1994 would have low flow fixtures installed due to the change in plumbing code. The results from the model confirm that homes built after this date use 500 gallons per month per household less than homes constructed before 1994.

Although the effect of passive conservation was estimated and found to be statistically significant at the 1 percent level, this estimate might be sharpened if the database were enlarged. The dummy variable for construction date may not be a completely accurate indicator, as some homes have voluntarily installed water saving devices to conserve water and reduce their water bills; however, the number of homes that have actively upgraded their plumbing and installed more efficient fixtures before 1994 is not likely to affect the results.

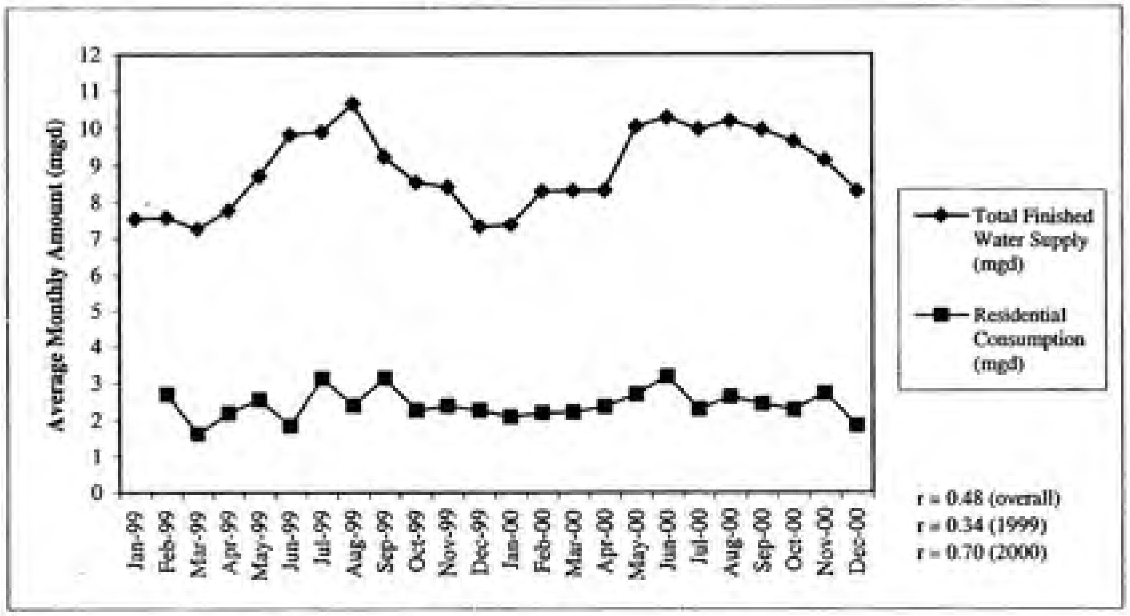
5.4 Difficulties with Analysis

Some of the difficulties encountered during this study include:

- Inconsistencies with Aquilium database
- Lack of information or missing values in databases
- Flawed precipitation variable

A potential problem concerns the Aquilium database that provides consumption data, which is the backbone of this report. Because the electronic system is relatively new, it seems that there were some errors, especially at the beginning in 1999. It is expected that by the year 2000 all the problems with the Aquilium system would have been resolved, but there seem to be some inconsistencies with the total finished water supplied to the OWASA service area and the residential consumption. Figure 5.1 compares the total water supply from the OWASA treatment plant to the residential customer consumption for the period February 1999 - December 2000.

Figure 5.1 – OWASA Total Finished Water Supply vs. Residential Consumption



The overall correlation coefficient (r) is 0.48, which implies that the pattern in residential consumption is only mildly related to that of the total finished water supply. As shown on Figure 5.1, the correlation coefficient for 1999 is 0.34; the consumption does not correspond to the supply very well, and even looks somewhat counterintuitive (i.e. high consumption in February, low consumption in June). For 2000, the consumption data appear to be more consistent with the finished water supplied and there is a correlation coefficient of 0.70, but there are still some noticeable inconsistencies such as high consumption in November. These discrepancies may be related to the Aquilium system, or possibly to meter reading practices. The Aquilium system should be investigated further to clear up some of these concerns.

Another concern is the lack of data for important variables such as the house construction date. It was originally thought that the lack of construction date information in the Parcels database could be solved by manually going through OWASA's forms to check when the water meter was set at the house, thus estimating the approximate date that the house was constructed. This process, however, was quite time consuming and not necessarily accurate, especially when determining the construction date of those houses around the crucial date of the plumbing code regulations in 1994. Also, it would likely be useful to have construction date as a continuous variable in the model, not just as a dummy representing before or after 1994.

Daily precipitation data are important so that the weather patterns are captured. For this report, it appears that using the number of days of precipitation to measure the effect of precipitation was reasonably accurate, but improvement might be possible. One of the problems is that the effect of precipitation on monthly consumption was positive in the model, whereas in practice precipitation is widely known to have a negative effect. A variable that takes into account antecedent precipitation as well as other factors such as evapotranspiration might be more appropriate.

5.5 Recommendations for Further Work

Some tasks to consider for further work include verifying the Aquilium database, collecting additional secondary data, and collecting primary data. Upon completion of these tasks, further analysis could be conducted to confirm and enhance the results from this report.

Verifying the validity of the Aquilium database could improve the quality of the results. The collection of additional secondary data would include gathering more information on the construction date of houses. Since only 20 percent of the Sample contained construction date information, supplementing this information would be very useful because the construction date appears to be such a key variable in determining passive conservation effects.

If OWASA is interested in refining the analysis and identifying additional variables associated with monthly consumption, primary data in the form of a household survey would probably be needed. The survey would be used to obtain additional local household characteristics and demographic information. The effects of passive conservation and indoor versus outdoor use may be refined by collecting data via a household survey.

Instead of using construction date to determine the effect of passive conservation, information on the plumbing fixtures could be used. In TM3.3 (CH2M-Hill, 2000), the percent and number of low-flow and ultra low flow toilets were assumed using information obtained from the AWWARF study; no local data have been collected, and the study did not include any locations in the southeast. In a local household survey, data can either be collected regarding whether or not the home has water saving devices or the number or percent of those fixtures in the home.

Information on lawn, garden and car washing practices, whether or not the household has a pool, or if there is any use of alternative sources of water (such as an irrigation well) would be helpful to refine indoor versus outdoor uses.

Additional variables could also be included in the regression analysis if OWASA is interested in identifying additional factors that affect consumption. For example, data on the household's attitude towards conservation (i.e. replacement of fixtures, voluntary leak detection) is useful to determine if public education would make a difference in consumption. Other factors such as the number of people per household can also be included. In the AWWARF study (Mayer et al., 1999), the total household indoor water use increased as the number of people in the household increased, but per capita use decreased, suggesting an efficiency associated with an increase in the number of people per household. A variable that indicates whether the customer rents or own the house may also be useful as there may be a difference between the two groups.

6.0 References

Billings, R. B., and W. M. Day. "Demand management factors in residential water use: The southern Arizona experience." Journal of the American Water Works Association. Vol. 81, No. 3. March 1989. pp. 58-64.

Boardman, Greenberg, Vining, and Weimer. Cost-Benefit Analysis: Concepts and Practice. Prentice-Hall, Inc. New Jersey. 1996. p. 307.

CH2M-Hill. Technical Memorandum 3.1. "Water Demand Forecasts." June 18, 1999. Prepared for the Orange Water & Sewer Authority. Accessed on-line at http://www.owasa.org/ on 1/15/00.

CH2M-Hill and PMCL. Technical Memorandum 3.2. "Baseline and Alternative Water Demand Forecasts." September 18, 1999. Prepared for the Orange Water & Sewer Authority. Accessed on-line at http://www.owasa.org/ on 1/21/01.

CH2M-Hill and PMCL. Technical Memorandum 3.3. "Long-Term Water Demand Forecasts with Conservation." January 24, 2000. Prepared for the Orange Water & Sewer Authority. Accessed on-line at http://www.owasa.org/ on 1/21/01.

Dempsey, Caitlin. "Geographic Information Systems: State Plane Coordinate System." March 27, 2000. Accessed on-line at http://gis.about.com/science/gis/library/weekly/aa032700.htm on 4/13/01.

DeOreo, William Butler, et al. "Flow Trace Analysis to Assess Water Use." Journal of American Water Works Association. Vol. 88, No.1. Jan 1996. pp. 79-90.

Environmental News Network (ENN). "Bill targets water-saving appliances." September 1, 1999. Accessed on-line at http://www.enn.com/enn-news-archive/1999/09/090199/lowflow_5042.asp on 2/5/01.

Environmental Protection Agency (EPA). "High Efficiency Toilets." Office of Water. January 2001. Accessed at http://www.epa.gov/OWM/toilets.htm on 2/5/2001.

Espey, M., Espey, J. and Shaw, W.D. "Price Elasticity of Residential Demand for Water: A Meta-Anaysis." Water Resources Research. Vol. 33, no. 6. June 1997. pp. 1369-1374.

Holland, Edward A. "*Water Supply: A 50-Year Vision for The Community.*" Prepared by Orange Water & Sewer Authority. May 1, 2000. Accessed online at http://www.owasa.org/quarry/supply.htm on 4/13/01.

Huston, Susan S. "Water Availability, Use, and Estimated Future Water Demand in the Upper Duck River Basin, Middle Tennessee." U.S. Department of the Interior, U.S. Geological Survey. Denver, CO. 1993.

Kerwin, Ed and Pelletier, Diane L. "*OWASA Executive Director's 2000 Annual Report*." Prepared by Orange Water & Sewer Authority. September 1, 2000. Accessed online at http://www.owasa.org/quarry/supply.htm on 5/14/01.

Litke, David W. and Kauffman, LeRoy F. "Analysis of Residential Use of Water in the Denver Metropolitan Area, Colorado, 1980-1987." Prepared in cooperation with the City and County of Denver, Board of Water Commissioners. Published by U.S. Geological Survey. Denver, CO. 1993.

Mayer, Peter W., DeOreo, William B., et al. <u>Residential End Uses of Water</u>. Published by the American Water Works Association Research Foundation (AWWARF). 1999.

Michelsen, Ari M. et al. "Nonprice Water Conservation Programs as a Demand Management Tool." Journal of the American Water Resources Association. Vol. 35, No. 3. June 1999. pp. 593 – 602.

Moreau, David. "Estimating Benefits of Water Conservation to a Southeastern City." Presented at Water Forum '92, sponsored by the American Society of Civil Engineers. Baltimore, MD. 1-2 August 1992.

Nieswiadomy, M. L. "Estimating urban residential water demand: Effects of price structure, conservation, and education." Water Resources Research. March 1992. Vol. 28, No. 3. pp.609-615.

Orange Water & Sewer Authority (OWASA). "OWASA Considers 'Seasonal' Water Conservation Rates." The Blue Thumb: The OWASA Newsletter. Vol. 10, No. 2. March 2001.

Planning and Management Consultants, Ltd. (PMCL). "IWR-MAIN Water Demand Management Suite." 1998. Accessed on-line at http://www.iwrmain.com on 1/12/01.

United States Geological Survey (USGS). "Water-Use Fact Sheet." 10 April 1996. Accessed on-line at http://water.usgs.gov/watuse/wufactsheet.htm on 2/5/01.

Ushikubo, Toshiyuki. "How to Control Water Demand." Water Supply. Vol. 17, nos. 3/4. Sydney, Australia. 1999. pp. 351-357.

Wang, Young-Doo, et al. "Evaluating the Persistence of Residential Water Conservation: A 1992-1997 Panel Study of a Water Utility Program in Delaware." Journal of American Water Works Association. Vol. 35, no. 5. October 1999. pp. 1269-1276.

Wooldridge, Jeffrey M. <u>Introductory Econometrics: A Modern Approach</u>. South-Western College Publishing. New York. 2000.

For this report, water consumption is adjusted using the date of the bill; therefore, a billing cycle is assigned for each month, and the overall billing cycle assigned by OWASA is not used. In addition, a billing cycle of 000 is assigned to a customer for any month in which the bill and consumption amounts are both zero, and each cycle is assumed to correspond to the dates shown in Table A.1.

Table A.1 –Assumptions for Billing Cycle and Meter Readings

Billing Cycle	**Range of Billing Dates**	**Assumed Date of Meter Reading**
000	No Bill	No meter reading
500	1st - 10th of Current Month	30th of Previous Month
600	11th - 20th of Current Month	10th of Current Month
700	21st- 31st of Current Month	20th of Current Month

Table A.2 shows the general method used in this study for normalizing the monthly consumption from the Aquilium database for each customer. The consumption for the current billing statement is noted as "Current" and the amount of consumption from the previous bill is noted as "Previous."

Table A.2 - Calculations for Normalized Monthly Consumption

Normalized Consumption for Previous Month				
Previous Billing Cycle	Current Billing Cycle			
	000	500	600	700
000	0	0	1/3*Current	2/3*Current
500	Previous	Previous	Previous + 1/3*Current	Previous + 2/3*Current
600	2/3*Previous	2/3*Previous	2/3*Previous + 1/3*Current	2/3*Previous + 2/3*Current
700	1/3*Previous	1/3*Previous	1/3*Previous + 1/3*Current	1/3*Previous + 2/3*Current

Appendix B **Illustrative Sample of Aquilium Database**

Customer ID	Location ID	Service Address	Unit	Customer Last	Customer First	Billing Address	Town	Phone	Consum0299
112485	05054050	118 GLENDALE DR	01	LAMBERT	BRENT A	118 GLENDALE DR	CHAPEL HILL	000-933-7887	
119745	05102460	11-A DAVIE CR	02	MACHEN	MARTIN	710 AIRPORT RD APT F-7	CHAPEL HILL	919-969-8898	
119810	05103025	205 MARILYN LN	01	PITZ	GORDON	205 MARILYN LN	CHAPEL HILL	919-960-3889	
121289	05150720	1213 HILLVIEW RD	01	GOLDMAN	LAUREL	1213 HILLVIEW RD	CHAPEL HILL	919-968-8338	
119663	05151260	1109 VALLEY PARK DR	01	SERIO	JENNIFER	209 JUSTICE ST	CHAPEL HILL	919-968-6175	
100404	05151380	1104 VALLEY PARK DR	01	LANGHOFF	GREGORY S	1104 VALLEY PARK DR	CHAPEL HILL	000-967-0737	7
100410	05151556	200 VALLEY PARK DR	01	ROSEN	LINDSEY	3115 ANNADELLE LN	CHAPEL HILL	000-009-4292 Ext. 5900	9
100440	05152390	199 VALLEY PARK DR	01	SACKS	DANIEL	331 TERRASTONE PL	CHAPEL HILL	008-139-8008 Ext. 2000	4
121493	05152680	102 PLANT RD	01	DUNN	ALVIS E	102 PLANT RD	CHAPEL HILL	919-933-4781	
100450	05153700	109 PLANT RD	01	VOLLMER	KIRSTEN	109 PLANT RD	CHAPEL HILL	000-009-6763 Ext. 76	6
119325	05153740	107 PLANT RD	01	GAUTHIER	CASSANDRA	408 NORTH ST	CHAPEL HILL	919-942-1965 Ext. 7345	
121904	05153780	103 PLANT RD	01	HARVEY	DAVID	103 PLANT RD	CHAPEL HILL	919-933-7274	
121566	05200320	16 WILLOW TERR	02	SILVERMAN	JENNA	1002 WILLOW TERR APT 16	CHAPEL HILL	919-929-5031	
121694	05201600	78 WILLOW TERR	02	LEHMAN	KRISTEN	1002 WILLOW DR APT 78	CHAPEL HILL	919-933-1359	
119022	05253540	404 HICKORY DR	01	LINDSAY	PAUL	404 HICKORY DR	CHAPEL HILL	Unknown	9
121137	05254040	414 RIDGEFIELD RD	01	EPPICH	SIMONE	414 RIDGEFIELD RD	CHAPEL HILL	919-933-0213	
121714	05301220	1306 WILDWOOD DR	01	MONAHA	KEVIN	1306 WILDWOOD DR	CHAPEL HILL	919-933-7879	
100779	05301330	110 DEERWOOD CT	01	YOUNG	BRADLEY W	119 STANDISH DR	CHAPEL HILL	000-009-2909 Ext. 8100	10
121597	05356033	7 FRANCES ST	01	TENOEVER	JOE	7 FRANCES ST	CHAPEL HILL	919-967-0166	
121474	05358146	305 HELMSDALE DR	01	COSTELLO	JOHN M	305 HELMSDALE DR	CHAPEL HILL	919-408-0522	
104356	05358430	132 DONEGAL DR	01	SMITH	SIDNEY	132 DONEGAL DR	CHAPEL HILL	919-929-6689	
105353	05358505	104 GALWAY DR	01	BOWMAN	CHRISTY F	104 GALWAY DR	CHAPEL HILL	919-933-5534	
121686	05359266	107 BLACK OAK PL	01	MAITLAND	REBECCA	107 BLACK OAK PL	CHAPEL HILL	919-929-8175	
101058	05359551	105 SHEFFIELD CR	01	SCOTT	LEE	105 SHEFFIELD CR	CHAPEL HILL	919-933-9463	
113315	05359657	400 NOTTINGHAM DR	01	LOVE	HAROLD	400 NOTTINGHAM DR	CHAPEL HILL	000-408-0431	
121933	05410650	821 TINKERBELL RD	01	FLETCHER	STEPHEN C	821 TINKERBELL RD	CHAPEL HILL	919-933-2524	
101577	05434800	207 CHIPPOAKS DR	01	HOSTETLER	ROBERT	207 CHIPPOAKS DR	CHAPEL HILL	000-933-2703	8
121740	05435320	111 MIDDLEBROOK DR	01	CIZEK	GREGORY J	111 MIDDLEBROOK CT	CHAPEL HILL	919-401-5359	
101701	05439215	106 COVINGTON DR	01	KANEKO	KAZUYOSHI	PO BOX 37	CHAPEL HILL	009-199-6984 Ext. 04	9
102426	05439578	94 PERRY CREEK DR	01	GUY	CYNTHIA D.	2912 BRITNEY POINT LANE	CHAPEL HILL	919-933-4678	
121565	05440100	511 COLONY WOODS DR	01	SONG	ALLEN	511 COLONY WOODS DR	CHAPEL HILL	919-969-6887	
121838	05440110	509 COLONY WOODS DR	01	HEIZER	MARK	PO BOX 16291	CHAPEL HILL	919-928-9777	
101925	05452550	1805 EPHESUS CH RD	01	RAVITCH	MARGARET	1805 EPHESUS CH RD	CHAPEL HILL	000-000-0000 Ext. 00	8

Appendix B

Illustrative Sample of Aquilium Database

Customer ID	Consum0399	Consum0499	Consum0599	Consum0699	Consum0799	Consum0899	Consum0999	Consum1099	Consum1199	Consum1299	Consum0100	Consum0200
112485										3	3	6
119745					7	4	6	7	6	5	4	6
119810										3	5	6
121289								2	3	1	2	6
119663					1	2	2	2	12	9	3	6
100404	6	7	3		9	7	8	5	4	4	11	4
100410	5	8	4		7	4	3	3	2	3	2	5
100440	3	3	1		7	3	1	2	1	1	1	5
121493									2	3	3	6
100450	4	4	1		5	3	4	3	4	4	4	7
119325	5	4	1		3	2	3	3	2	3	1	6
121904											2	6
121566										2	2	6
121694										1	3	6
119022	8	9	3		8	7	10	3	4	3	4	3
121137								4	6	3	4	6
121714										0	3	6
100779	7	7	2		10	9	10	5	8	4	7	18
121597										3	3	6
121474										3	3	6
104356											1	6
105353											5	6
121686										1	1	6
101058											2	6
113315										1	9	6
121933											3	6
101577	8	11	4		21	13	12	6	8	4	3	6
121740											3	6
101701	8	7	2		5	7	5	6	7	5	5	12
102426											2	6
121565									1	3	2	6
121838											2	6
101925	7	7	2		9	5	7	7	8	8	7	6

Appendix B

Illustrative Sample of Aquilium Database

Customer ID	Consum0300	Consum0400	Consum0500	Consum0600	Consum0700	Consum0800	Consum0900	Consum1000	Consum1100	Consum1200
112485	3	3	4	4		8	5	3	6	4
119745	1	4	5	5	6	13				
119810	8	5	8	8		17	9	11	11	5
121289		1		1		2	3	2	4	1
119663	62	2	3	2	3					
100404	1									
100410	3									
100440	0									
121493		2	3	1		1	2	1	3	1
100450	1									
119325	22	3	3							
121904	1	3	4	3	4	4	6	6	8	4
121566		2	4	2	2	3	4	2	4	2
121694		2	2	1	2	2	1	2	3	2
119022	3									
121137	1	4	4	5	4	5	4	3		
121714		3	4	5	3	2	3	3	6	5
100779	6									
121597		2	4	5	3	4	5	5	4	2
121474		3	4	4	3	5	5	4	3	2
104356	2	4	7	35	23	29	14	5	10	4
105353	3	6	7	36	27	26	18	17	17	7
121686		5	4	7	4	5	5	3	3	2
101058	1	4	14	32	21	31	38	17	53	21
113315		11	34	18	20	16	18	24	17	6
121933	5	5	8	5	5	4	7	7	10	7
101577	2									
121740	5	4	5	7	4	5	4	5	9	3
101701	3									
102426	3	3	5	6	3	3	3	3	6	3
121565		4	4	5	4	4	4	3	5	3
121838	2	5	6	8	6	5	4	6	8	4
101925	4									

Data Display Results

Date Range: From 12/01/1998 To 12/31/2000
All Dates Displayed in Time Zone: LST

CHAPEL HILL 2 W, NC (UCAN: 14030,COOP: 311677)

Date	SUM Precip (In)	AVG Max Temp (F)	AVG Min Temp (F)	AVG Mean Temp (F)	SUM Cool Deg Days (F)	SUM Heat Deg Days (F)
1998/12	4.03	56.81	36.03	46.42	4	573
1999/01	7.62	57.03	32	44.52	2	628
1999/02	2.33	56.64	31.11	43.88	0	584
1999/03	3.54	60.13	33.42	46.77	0	558
1999/04	4.62	72.7	46.97	59.83	43	192
1999/05	1.1	77.74	53.65	65.69	82	54
1999/06	2.92	82.7	63	72.85	248	4
1999/07	2.86	89.68	70.45	80.06	481	6
1999/08	5.45	90.65	69	79.82	466	0
1999/09	24.01	79.1	59.03	69.07	153	22
1999/10	2.54	69.13	46.55	57.84	17	231
1999/11	2.52	68.43	41.33	54.88	0	297
1999/12	1.74	54.9	30.74	42.82	0	683
2000/01	4.61	49.16	26.42	37.79	0	836
2000/02	2.25	57.55	32	44.78	0	581
2000/03	2.68	66.58	40.26	53.42	11	361
2000/04	6.25	68.23	45.07	56.65	16	261
2000/05	2.53	82.42	56.77	69.6	181	30
2000/06	3.19	87.13	65.6	76.37	351	0
2000/07	7.69	85.03	66.97	76	350	0
2000/08	5	85.32	65.23	75.27	327	0
2000/09	4.1	78.36	59.45	68.73	154	43
2000/10	0.26	74.74	45.97	60.35	31	168
2000/11	2.37	59.38	34.86	47.12	1	511
2000/12	1.42	46.36	25.68	36.02	0	720
Sum/Avg	107.63	70.46	47.32	58.88	2918	7343

The status of Daily data in the CIRRUS database is as follows:

Raw data available through '27-DEC-00'.
Preliminary data from National Climatic Data Center through 'AUG-2000'.
Final quality-controlled data from National Climatic Data Center through 'JUN-2000'.

Daily Readings at the OWASA Water Treatment Plant

Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)	Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)
January	1	67	28	47.5	0	February	1	36	20	28	0
	2	67	36	51.5	0		2	41	20	30.5	0
	3	68	41	54.5	0		3	42	22	32	0
	4	74	50	62	0		4	52	28	40	0
	5	68	33	50.5	0.50		5	52	28	40	0
	6	46	20	33	0		6	46	28	37	0
	7	52	20	36	0.05		7	51	28	39.5	0
	8	58	22	40	0		8	59	29	44	0
	9	55	34	44.5	0.02		9	50	28	39	0
	10	55	37	46	0.56		10	58	28	43	0
	11	66	36	51	0.43		11	65	28	46.5	0
	12	69	25	47	0		12	72	36	54	0.27
	13	63	21	42	0		13	37	31	34	0.52
	14	70	24	47	0		14	52	31	41.5	0.42
	15	40	14	27	0		15	66	40	53	0
	16	49	23	36	0		16	55	36	45.5	0
	17	62	29	45.5	0		17	69	41	55	0
	18	44	21	32.5	0.26		18	51	32	41.5	0.47
	19	30	20	25	0.12		19	59	33	46	0.04
	20	41	23	32	0.37		20	69	31	50	0.03
	21	46	18	32	0		21	53	28	40.5	0
	22	34	14	24	0		22	52	27	39.5	0
	23	34	19	26.5	0.05		23	57	27	42	0
	24	33	24	28.5	0.34		24	66	30	48	0
	25	37	23	30	1.32		25	70	40	55	0
	26	37	15	26	0.12		26	78	47	62.5	0
	27	34	10	22	0		27	75	49	62	0
	28	33	2	17.5	0		28	72	49	60.5	0.50
	29	45	1	23	0		29	64	33	48.5	0
	30	38	25	31.5	0.31						
	31	33	23	28	1.22						

Daily Readings at the OWASA Water Treatment Plant

Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)
March	1	67	32	49.5	0
	2	74	41	57.5	0
	3	64	36	50	0
	4	64	37	50.5	0
	5	54	33	43.5	0
	6	70	33	51.5	0
	7	72	40	56	0
	8	76	45	60.5	0
	9	84	49	66.5	0
	10	81	55	68	0
	11	81	56	68.5	0
	12	81	53	67	0.41
	13	53	28	40.5	0
	14	54	29	41.5	0
	15	65	29	47	0
	16	71	44	57.5	0
	17	67	49	58	0.38
	18	66	32	49	0
	19	49	32	40.5	0
	20	58	37	47.5	0
	21	52	44	48	1.32
	22	56	42	49	0
	23	58	44	51	0
	24	65	38	51.5	0
	25	72	38	55	0
	26	79	47	63	0.09
	27	74	40	57	0
	28	65	42	53.5	0.45
	29	70	41	55.5	0
	30	62	41	51.5	0.03
	31	60	41	50.5	0

Month	Date	Max Temperatur e	Min Temperatur e	Average Temperatur e	Total Precipiation (inches)
April	1	67	38	52.5	0
	2	72	42	57	0
	3	68	51	59.5	0.04
	4	81	61	71	0.17
	5	67	35	51	0.10
	6	61	35	48	0
	7	80	47	63.5	0
	8	84	52	68	0
	9	75	36	55.5	1.50
	10	61	37	49	0
	11	75	41	58	0
	12	78	55	66.5	0.01
	13	76	44	60	0
	14	44	40	42	0.52
	15	53	41	47	0.43
	16	62	53	57.5	0.36
	17	80	57	68.5	0
	18	80	52	66	1.10
	19	52	46	49	0
	20	73	47	60	0
	21	77	48	62.5	0
	22	78	45	61.5	0
	23	63	42	52.5	0
	24	71	43	57	0
	25	67	47	57	0.16
	26	52	40	46	0.08
	27	62	40	51	0.33
	28	65	49	57	0.01
	29	54	43	48.5	1.42
	30	69	45	57	0.02

Daily Readings at the OWASA Water Treatment Plant

Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)	Month	Date	Max Temperatur e	Min Temperatur e	Average Temperatur e	Total Precipiation (inches)
May	1	76	46	61	0	June	1	80	53	66.5	0
	2	80	46	63	0		2	90	58	74	0
	3	77	56	66.5	0		3	94	69	81.5	0
	4	77	50	63.5	0		4	90	63	76.5	0.1
	5	79	49	64	0		5	76	63	69.5	0.13
	6	83	54	68.5	0		6	70	65	67.5	0.13
	7	87	59	73	0		7	77	52	64.5	0
	8	88	60	74	0		8	77	53	65	0
	9	88	63	75.5	0		9	81	53	67	0
	10	87	64	75.5	0		10	88	61	74.5	0
	11	87	53	70	0		11	90	64	77	0
	12	82	53	67.5	0		12	92	65	78.5	0
	13	90	59	74.5	0		13	94	67	80.5	0
	14	92	59	75.5	0		14	96	74	85	0
	15	79	56	67.5	0		15	94	67	80.5	0.2
	16	73	49	61	0		16	92	69	80.5	0.3
	17	75	49	62	0		17	90	73	81.5	0
	18	80	58	69	0		18	90	73	81.5	0
	19	86	65	75.5	0		19	91	72	81.5	0.14
	20	92	67	79.5	0		20	88	68	78	0.38
	21	91	67	79	0		21	75	67	71	0
	22	91	64	77.5	2.15		22	89	72	80.5	0
	23	82	55	68.5	0.01		23	86	65	75.5	0
	24	82	55	68.5	0		24	90	66	78	0
	25	88	67	77.5	0.00		25	91	70	80.5	0
	26	81	57	69	0.05		26	94	72	83	0.03
	27	82	57	69.5	0.00		27	94	71	82.5	0
	28	88	62	75	0.00		28	91	71	81	1.02
	29	82	61	71.5	0.32		29	87	70	78.5	0.56
	30	64	50	57	0.00		30	77	62	69.5	0.2
	31	66	50	58	0						

Daily Readings at the OWASA Water Treatment Plant											
Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)	Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)
July	1	84	61	72.5	0.02	August	1	87	70	78.5	0.39
	2	85	60	72.5	0		2	86	69	77.5	0.72
	3	88	62	75	0		3	87	70	78.5	0.07
	4	90	70	80	0.00		4	85	71	78	0.08
	5	90	71	80.5	0.02		5	86	67	76.5	0.61
	6	89	71	80	0.46		6	84	67	75.5	0
	7	88	70	79	0		7	90	70	80	0
	8	84	68	76	0.06		8	94	74	84	0
	9	84	69	76.5	0		9	93	74	83.5	0
	10	91	70	80.5	0		10	94	68	81	0.54
	11	96	74	85	0		11	89	68	78.5	0
	12	90	73	81.5	0		12	87	65	76	0
	13	78	69	73.5	0		13	83	60	71.5	0
	14	75	67	71	0.56		14	77	60	68.5	0.25
	15	85	66	75.5	0.72		15	84	60	72	0
	16	86	66	76	0.06		16	87	64	75.5	0
	17	87	65	76	0		17	92	65	78.5	0
	18	87	65	76	0		18	87	64	75.5	0
	19	91	66	78.5	0		19	90	67	78.5	0.17
	20	93	66	79.5	0		20	82	61	71.5	0
	21	81	66	73.5	0		21	78	56	67	0
	22	80	66	73	0.06		22	78	55	66.5	0
	23	80	67	73.5	0.20		23	81	55	68	0
	24	81	66	73.5	5.12		24	87	57	72	0
	25	76	63	69.5	0.07		25	87	67	77	0
	26	69	64	66.5	0.32		26	84	66	75	0
	27	77	66	71.5	0.02		27	85	66	75.5	0
	28	87	67	77	0.00		28	84	64	74	1.29
	29	90	66	78	0.00		29	80	65	72.5	0.10
	30	87	66	76.5	0.00		30	82	68	75	0.31
	31	87	70	78.5	0.00		31	75	69	72	0.47

Daily Readings at the OWASA Water Treatment Plant

Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)
September	1	85	72	78.5	0.20
	2	86	71	78.5	0.09
	3	83	71	77	0.24
	4	83	71	77	0.20
	5	77	69	73	0.54
	6	70	57	63.5	0.04
	7	68	57	62.5	0.00
	8	76	57	66.5	0.00
	9	81	59	70	0.00
	10	84	62	73	0.00
	11	84	62	73	0.00
	12	84	64	74	0.00
	13	85	64	74.5	0.00
	14	88	65	76.5	0.00
	15	85	69	77	0.12
	16	85	48	66.5	0.00
	17	71	45	58	0.00
	18	69	44	56.5	0.00
	19	67	57	62	0.53
	20	85	63	74	0.00
	21	86	64	75	0.00
	22	81	63	72	0.04
	23	81	62	71.5	0.57
	24	81	62	71.5	0.40
	25	87	64	75.5	0.00
	26	75	52	63.5	1.23
	27	64	52	58	0.01
	28	69	47	58	0.01
	29	74	48	61	0.00
	30	71	53	62	0.00

Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)
October	1	73	54	63.5	0
	2	73	55	64	0
	3	78	57	67.5	0
	4	85	57	71	0
	5	84	59	71.5	0
	6	85	59	72	0
	7	85	55	70	0
	8	69	40	54.5	0
	9	50	36	43	0
	10	55	34	44.5	0
	11	66	34	50	0
	12	71	36	53.5	0
	13	74	40	57	0
	14	79	42	60.5	0
	15	82	44	63	0
	16	82	43	62.5	0
	17	82	49	65.5	0
	18	75	51	63	0
	19	79	50	64.5	0
	20	74	43	58.5	0
	21	75	44	59.5	0
	22	77	45	61	0
	23	79	51	65	0
	24	70	42	56	0
	25	72	41	56.5	0.26
	26	74	48	61	0
	27	71	47	59	0
	28	77	53	65	0
	29	80	39	59.5	0
	30	67	33	50	0
	31	70	33	51.5	0

Daily Readings at the OWASA Water Treatment Plant

Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)	Month	Date	Max Temperature	Min Temperature	Average Temperature	Total Precipiation (inches)
November	1	68	33	50.5	0.00	December	1	51	25	38	0.00
	2	71	33	52	0.00		2	51	25	38	0.00
	3	73	34	53.5	0.00		3	40	28	34	0.06
	4	78	40	59	0.00		4	38	24	31	0.00
	5	72	51	61.5	0.03		5	49	20	34.5	0.00
	6	65	33	49	0.00		6	53	26	39.5	0.00
	7	65	33	49	0.00		7	42	25	33.5	0.00
	8	61	53	57	0.05		8	53	29	41	0.00
	9	76	54	65	0.02		9	62	34	48	0.00
	10	75	56	65.5	0.04		10	48	33	40.5	0.00
	11	69	39	54	0.00		11	38	33	35.5	0.03
	12	64	36	50	0.00		12	56	38	47	0.00
	13	62	35	48.5	0.00		13	57	27	42	0.00
	14	66	35	50.5	0.10		14	40	27	33.5	0.07
	15	59	30	44.5	0.43		15	45	33	39	0.03
	16	53	29	41	0.00		16	49	34	41.5	0.28
	17	52	29	40.5	0.11		17	67	35	51	0.71
	18	54	28	41	0.00		18	55	24	39.5	0.00
	19	44	31	37.5	0.06		19	47	23	35	0.00
	20	41	32	36.5	0.52		20	40	20	30	0.23
	21	44	25	34.5	0.00		21	34	17	25.5	0.00
	22	41	21	31	0.00		22	41	17	29	0.01
	23	44	21	32.5	0.00		23	40	16	28	0.00
	24	51	26	38.5	0.00		24	34	16	25	0.00
	25	48	32	40	0.03		25	48	24	36	0.00
	26	52	39	45.5	0.96		26	33	14	23.5	0.00
	27	51	38	44.5	0.02		27	36	13	24.5	0.00
	28	62	35	48.5	0.00		28	44	31	37.5	0.00
	29	62	33	47.5	0.00		29	37	22	29.5	0.00
	30	63	33	48	0.00		30	40	19	29.5	0.00
							31	35	19	27	0.00

ORANGE COUNTY – LAND RECORDS
DATA DICTIONARY
PARCELS COVERAGE

December 2000

Field	Creator Of Data	Comments
AREA	ESRI	Internal number "calculated" by size of polygon Do not use this number as the area of any individual Parcel size.
PERIMETER	ESRI	Internal calculated length around polygon.
PARCELS #	ESRI	Internal ID
PARCELS ID	ESRI	Internal ID (can be modified by user).
OLD PIN	OCLR	Made up of 10 characters – blending of the X,Y coordinates. Keyed in by staff – daily This field used to "JOIN" to main frame data.
GISTMBL	OCLR	Old Mapping number Township, Map, Block, and Lot
SUBCODE	OCLR	Keyed in by Land Records staff. Subdivisions with 5 or more lots.
TRACT	OCLR	Auto-created by main frame system Sequential numbering index by Township Ex. (1- 001003)
CREATION	OCLR Register of Deeds, Land Records, Main Frame	Automated Main Frame function – Date of when a parcel is created or transferred.

SIZE	OCLR	Land Records figures out size, keyed in on Public notice screen. S = square footage, A = Acres, L = One lot
	Tax Assessor	Decides if acreage is taxed by acreage or deeded size
USEVALUE	Tax Assessor	Value in field represents how much the individual is paying taxes on. Difference between the Land Value and Use Value.
OWNER	OCLR, Register of Deeds & Main Frame	Legal property owner (s)
PIN	OCLR	**<u>Official Orange County Parcel Identification Number</u>** 14 digit number which is unique to a parcel. Condos = .001 Parcel database will not reflect all the condo's – only the 1st record.
OTWP	OCLR	Old Township With specific field selected – good for searches by specific numbers
OMAP	OCLR	Old Map
OBLOCK	OCLR	Old Block
OLOT	OCLR	Old Lot

TMBL	OCLR	This is the old mapping number and is only unique at the time it is assigned, it may have been previously attached to a different parcel. It has the format Township.Map.Block.Lot
STATUS	OCLR	Codes assigned by Main Frame system use for Tax Assessing. A – Active. (Responsible for current tax bill.) A1 - New owner this year. Does not get this years tax bill. E – Exempt I – Inactive Parcel M – Merged (Property was merged.) O – Other (Taxed in Other County) P – Plat Split Inactive P1 – Plat Split Active S – Split (Property was split into multiple parcels.)
DESC	OCLR	Legal Description using abbreviations
BLDGS	Tax Office	Number of buildings on physical property Building defined as anything that has a tax value of minimum value.
LANDVALUE	Tax Office	"Assessed" tax value of the land.
HOUSEVALUE	Tax Office	"Assessed" tax value of buildings.
TOTALVALUE	Tax Office	The total of the Land value added to the house value. What you pay taxes on at the end of the year.

DATESOLD	OCLR	Date ownership changed – parcels
RVSTAMPS	OCLR, Register of Deeds	Revenue stamps put on property when sold. Percent of sales price. ($2/per thousand = rate after Aug. 1, 1991 $1/per thousand = rate prior to Aug. 1, 1991 $1.10/per thousand = rate prior to 1967)
RATECODE	OCLR	Code is assigned to parcel depending on where the parcel is located. There is a tax rate associated with each code (00-32). See tax rate sheet.
ZONEJUR		Do not use this field. Get current information from municipalities.
ZONING		Do not use this field. Get correct, current information from municipalities.
CITY	OCLR, Register of Deeds	Where the tax bill is sent. **Property owner's address.**
STATE	OCLR, Register of Deeds	Where the tax bill is sent. **Property owner's address.**
ZIP	OCLR, Register of Deeds	Where the tax bill is sent. **Property owner's address.**
USE	Tax Office	2 = Agriculture 3 = Horticulture 4 = Forestry

ERCDCODE	Planning Office ERCD	Environmental Resource Conservation Dept.Classification Code Helps ERCD to identify related parcels. Environmental Codes: CARRBOROPK, CHPARK, DUKEFOREST, HILLSPARK, JOINTOWNER, MEBANEPARK, NCPARK-ENO, OCPARKS, OWASA, SPORTSPLEX, UNCLAND, USA-JORDAN.
BLDGDESC	Tax Office	F = Frame, M= Mason (brick) 10 = 1 story, 15 = 1 ½ , 17 = 1 ¾, 20 = 2 story, 3 = 3 stories
BLDGMTHD	Tax Office	R – Residential C – Commercial O - Outbuilding Computer Prices P - Price insert (estimate value)
ECON	Tax Office	Percent % deduction for market value
PHYS	Tax Office	Physical depreciation of building, based on year and current condition. Opinion decision.
VALUE	Tax Office	Value of ONE building on property. Calculated Market Value
BLDGTRCT	Tax Office	Tract number .ext is the first building on tract.
LANDMTHD	Tax Office	A = Acres C = Commercial S = Square footage L = Lot X = No Lot size (works like price insert)

LANDTYPE	Tax Office (Depends on Land Methods)	9 = Rural 1 = Homesite 2 = Agriculture 3 = Horticulture 4 = Forestry 6 = Commercial 8 = Pricing difference
FRONTACT	Tax Office	ACTUAL front feet on lots – only shows if Land method (see above field description) = 2.
FFEFF	Tax Office	Front Foot Effective Front Foot – tries to "square up" lot. Calculates the difference between rear and front property lines.
UNITPR	Tax Office	Unit Price – Price per acre or price per square foot or ffp (front foot price)
REAR	Tax Office	Back size in linear feet.
EFF DPTH	Tax Office	Calculates the difference from size to size and tries to square up lot.
SZADJ	Tax Office	Size Adjustment – on lots. Percent square up entire lot front to back, side to side.
HOMESITE	Tax Office	Will only see this field if Method A or (Met A) or Type 9 is present. P1 = $2,000 A1 = $4,000 G1 = $6,000 Depends of price of house, this is added to the overall value of land.

SQFT	Tax Office	Square feet of LAND. Method S.
ADJ	Tax Office	List of Adjustments Topo, easements, no perks, etc.
MKTVAL	Tax Office	Market value of land.
BASEVAL	Tax Office	Value that is adjusted o more than one acre of property. Adjustment per acre.
SOILTYPE	Tax Office	Land soil type – GEB,GED Value per acre
BLDGID	Tax Office	Building Identification number. Since their can be many buildings on a parcel, the building information listed is for this building id number.
AREAOF	Tax Office	Normally area calculated by the computer sketch.
BLDGTYPE	Tax Office	Type of Improvement on property. AA – Attached Addition AG – Attached Garage CA – Carport DK – Deck GB – Garage in Basement GP – Glazed Porch (glassed in porch) LG – Living quarters above detached garage. LQ – Living quarters above attached garage. MA – Main section.(Highest story on multi-story) OP – Open Porch PA – Patio PR – Patio with Roof

		SA – Special Addition (Storage Area)
CLASS	Tax Office	Occupancy 1-Single Family 2 – Two Family (duplex) 3 – Three Family (triplex)
STYLE	Tax Office	Construction Style C – Conventional R- Ranch S – Split Level (Tri-level) F – Split Foyer (Bi-level) T-Contemporary K-Deck House D-Dome L-Log
STORY	Tax Office	Story Height 05-1/2 story (usually living quarters over garage.) 10-One Story 12-One and One-Quarter Story 15-One and One-Half Story 17-One and Three-Quarters Story 20-Two Story 25-Two and One-Half Story 30-Three Story
EXTWALL	Tax Office	Exterior Wall F-Frame or Equal M-Masonry S-Stone A-Aluminum
ATTAREA	Tax Office	Attic Finish (Blank if no attic) 00-Unfinished Attic (Floor and stairs only) 25-One Quarter Finished 50-One Half Finished 100-Fully Finished and Divided (2 or more rooms)
FOUND	Tax Office	Foundation M-Masonry Foundation 100% Crawlspace or 100% Basement Q-Masonry Foundation 75% Basement H-Masonry Foundation 50% Basement T-Masonry Foundation 25% Basement S-Slab Foundation P-Pier Foundation

RVALUE		
BAMTAREA	Tax Office	Approximate Percentage Of **Basement Area** Under Each Segment. Blank if no Basement. 25-1/4 Basement 50-1/2 Basement 75-3/4 Basement 100- Full Basement
BSMTFIN	Tax Office	Indicates what percentage of the indicated basement area is finished. A 50% basement area completely finished would be 100% finished. 0-None of the basement area is finished. 25-1/4 of basement area is finished. 50-1/2 of basement area is finished. 75-3/4 of basement area is finished. 100-All of basement area is finished.
ROOFING	Tax Office	Roofing style and composition. **Style** **Composition** G-Gable S-Shingles H-Hip W-Wood Shingles R-Gambrel M-Metal M-Mansard R-Roll F-Flat T-Tile
NOROOMS	Tax Office	Total Number Of Rooms; excluding bathrooms and utility rooms.
NOBDRMS	Tax Office	Number Of Bedrooms
INTFIN	Tax Office	Internal Finish (Most representative finish for main areas and additions.) D-Drywall P-Panel L-Lathe and Plaster U-Unfinished

FLOOR	Tax Office	Floors (Most representative finish for main areas and additions.) H-Hardwood W-Wall to Wall Carpet T-Tile A-Asphalt Tile C-Concrete P-Plywood Z-Terrazzo
LIGHT	Tax Office	Lights (Blank)
BUILTIN	Tax Office	Built-Ins (Blank)
HEAT	Tax Office	Heating and Air Conditioning (If air conditioning exists an "AC" is added to heating code. e.g. 1-AC) 1-Forced Air (Heating system with ducts) 2-Floor or Wall Furnace(wood stoves, stand alones) 3-Steam or Hot Water System 4-Combo Heat and Air Cond.(Heat pump/gas pack) 5-Electric Baseboard Heating Units (No ducts) 6-Solar 7-None or Space Heat or Wood Heat
AIRCOND	Tax Office	Air Condition Y- Yes N or Blank-No
PLUMBING	Tax Office	Total number of baths and number of fixtures above the standard five fixtures-kitchen sink, water heater, bathroom sink, tub or shower, and commode. 0/0-No Plumbing 0/1-Water Only 0/2-Two Fixtures 1/0-Standard One Bath, No extra fixtures 1.5/2-One and one-half bath with two extra fixtures. 2/3-Two baths, three extra fixtures 2.5/5 Two and one-half baths, five extra fixtures.

FIREPLACE	Tax Office	Total number of fireplace openings.
GRADEDIF	Tax Office	Indicate appropriate quality class and quality factor. There is a 30 degree range between each factor. The factor can be any plus or minus range between each class. (e.g. B+10 is 140, B-10 is 120). **<u>Class</u>** **<u>Factor</u>** A 160 B 130 C 100 D 70 E 40
DESIGNFAC	Tax Office	Indicate appropriate design factor if any. It is a three digit entry with a decimal point after first digit. (Ex) 0.05 for cathedral ceiling, 0.10 for mason wall.
EFFAGE	Tax Office	Physical Depreciation-Indicates estimated loss of value from replacement cost new, due to physical deterioration. (Expressed as a percentage).
COMPLETED	Tax Office	Year Built
OWNER2	OCLR, Register of Deeds & Main Frame	Line 2 of Legal property owner (s).
X-COORD	ESRI	X Coordinate of the centroid of the parcel polygon given in stateplane NAD83 coordinates.
Y-COORD	ESRI	Y Coordinate of the centroid of the parcel polygon given in stateplane NAD83 coordinates

Appendix F

Illustrative Sample of Parcels Database

OwnerLast	OwnerFirst	Owner2	Property Description	Billing Address
BOWMAN	FREDERICK O	& ELIZABETH S	P/O #4 DANIEL A ALBRIGHT	12723 MOREHEAD GOVERNORS CLUB, CHAPEL HILL
EMORY	SARA LYNNE		#3 SWEET BUSH SUBDIV P32/45	5304 SWEET BUSH RD, CHAPEL HILL
WOODY	ANNIE RUTH		#2 SWEET BUSH P32/45	5305 SWEETBUSH RD, CHAPEL HILL
SPARROW	PAUL B JR	& MADELINE F	#2 ELM GROVE P47/137	5315 ELM GROVE LN, CHAPEL HILL
BALES	PHILIP CHARLES		#4 SWEET BUSH ROAD P32/45	5316 SWEET BUSH RD, CHAPEL HILL
EASON	FREDERICK J JR		#1 SWEET BUSH SUBDIV P32/45	5317 SWEET BUSH RD, CHAPEL HILL
FAUCETTE	LARRY D	& SHELLEY R	#1 ELM GROVE P47/137	5321 ELM GROVE LN, CHAPEL HILL
HOULT	PETER	& LINDA	#1 STONE CURRIE P78/144	73201 BURRINGTON, CHAPEL HILL
VANMIDDLESWORTH	FRANK L	& ANN M EDISON	#57 PH 3B ROBERSON PLACE P82/8	102 RED SUNSET PL, CARRBORO
HART	TIMOTHY LIONEL		#43 PH 3B ROBERSON PLACE P82/8	103 RED SUNSET, CARRBORO
LEINENWEBER	DANA	& STEPHEN	#56 PH 3B ROBERSON PLACE P82/8	104 RED SUNSET PL, CARRBORO
DELOACH	STEVE	& LAURA HENDERSON (W)	#42 PH 3B ROBERSON PLACE P82/8	105 RED SUNSET PL, CARRBORO
WILSON	JOYCE L	& ALTON L (H)	#2 ROBERTS ST	105 ROBERTS ST, CARRBORO
TAYLOR	EDNA M	& JOYCE L MINOR	4LINCOLN HTS	109 ROBERTS ST, CARRBORO
FRIEDMAN	JARED S	& BETH B SHAPIRO	#53 PH 3B ROBERSON PLACE P82/8	110 RED SUNSET, CARRBORO
BLAU	PETER M	& JUDITH R	#39 REC PH 3B ROBERSON PL	111 RED SUNSET DR, CARRBORO
HAYES	RUBEN H	& JACQUELINE H	#5 LINCOLN HEIGHTS	111 ROBERTS ST, CARRBORO
ESCOBAR	ARTURO	MAGDA E CORREDOR	#25 PH 3B ROBERSON PLACE P82/8	112 PURPLE LEAF PL, CARRBORO
SANFORD	GEORGE W JR	& RUTHENA	LT6 LINCOLN HTS	113 ROBERTS ST, CARRBORO
FOUST	MARY JANE		#D REC COLE HTS EXT 2 P57/168	142 LINCOLN LN, CHAPEL HILL
MILLER	RONNIE P	& JEAN S	W/S GREENSBORO ST	426 S GREENSBORO ST, CARRBORO
EDWARDS	JAMES G	& ERNESTINE	5-J A CATES	428 S GREENSBORO ST, CARRBORO
GARAVAGLIA	PATRICIA E	& SHARON H COLLINS	INT SPARROWS POOL RD & GREENS-	436 S GREENSBORO ST, CARRBORO
CARVER	EDWARD JR		N/S MERRITT MILL RD	742 S MERRITT MILL RD, CHAPEL HILL
MICHAEL	MORROW INC	C/O BEEMER SAVERY HADLER	#41 PH 3B ROBERSON PLACE P82/8	P O BOX 3150, CHAPEL HILL
COMMONWEALTH	CONSTRUCTION	DESIGN INC	#28 PH 3B ROBERSON PLACE P82/8	P O BOX 5100, CHAPEL HILL
FARROW	LOLA M		#56 - 59 DAWSON-UPCHURCH	PO BOX 155, CARRBORO
DORRITY	CHARLES BRENT		35 - 46 & P/O 47 PACIFIC MILLS	PO BOX 369, CARRBORO
BREWER	ALLIE		12 BL B LINCOLN PARK	101 PRINCE ST, CARRBORO

ZIP	Area (sq ft)	X_Coord	Y_Coord	Class	LandValue	HouseValue	TotalValue	YearBuilt	Rooms	Bathrooms	AddlFixtures
27514	965513.61042	1924549.19567	828131		106326	19233	125559				
27516	45634.57030	1970184.83731	820204		39327	86927	126254				
27516-8167	48061.36292	1969988.53592	820205		40377	83714	124091				
27516-5109	94790.75115	1969461.09720	819835	1	66755	127628	194383	1987	7	2	3
27516-8167	51779.08340	1970188.87802	819950		49832	95633	145465				
27516	64451.55747	1969993.10324	819921		56466	129439	185905	1987			
27516	91498.30530	1969493.89842	819545	1	66323	124164	190487	1988	6	2	3
27514-8575	414659.54578	1970981.29865	825038		306600	839636	1146236				
27510	3811.66203	1979108.66431	784566		43969	147351	191320				
27510	6029.78122	1979242.21041	784499		40440	218800	259240				
27510-2381	3876.96472	1979110.67319	784523		43969	152670	196639				
27510	5812.85332	1979231.36408	784439		43197	193490	236687				
27510	10461.36577	1978734.62809	783222		34639	42809	77448				
27510-2323	9148.19681	1978847.41865	783224		32894	45147	78041	1956	6	1	0
27510	3350.93765	1979021.71134	784437		42073	151493	193566				
27510	6757.73417	1979115.71914	784319		35826	228474	264300				
27510	8990.62678	1978905.84307	783224		33375	53109	86484				
27510	4483.94817	1978913.26745	784522	1	40730	189148	229878	2000	6	3	5
27510-2323	10679.98194	1978975.94161	783222		38203	38727	76930	1952	4	1	0
27516	5499.31807	1979568.45022	784005		15410	46772	62182				
27510	8951.83077	1978468.64876	784370		54705	57089	111794				
27510-2333	8969.63932	1978469.07418	784296		54705	62086	116791	1952	5	1	0
27510	10816.08026	1978495.05385	783945		64264	61789	126053				
27514	10684.14106	1979527.12103	783153		42204	50828	93032				
27515	5017.41876	1979198.11859	784395		39974	151046	191020				
27515	4428.19399	1978909.70932	784366	1	43640	213516	257156	1999	7	3	5
27510	14003.70819	1978998.14103	783046		44154	51369	95523	1952			
27510	94466.73329	1978706.82844	784147		1887	94892	96779				
27510-2215	8580.06040	1977149.65647	784331		27569	67785	95354				

Subdivisions with houses constructed all after 1994 - streets are listed within each area

Cedars
Stable Rd

Culbreth Ridge
Gardner Cr
High Grove Dr
Weyer Dr

Englewood
Brookstone Ct
Englewood Dr
Westchester Pl
Woodmark Ct

Homestead Village
Brunswick Ct
Chesapeake Way
Hearthstone Ln
Portsmith Pl
Savannah Terrace

Hundred Oaks
Hayworth Dr
Jolyn
Lombard Dr
Miramar Dr
Oak Park Dr
Van Doren Pl

Hunt's Reserve
Bayberry Dr
Flagstone Ct
Morganscliff Ct
Quarry Pl
Rhododendron Ct
Silers Fen Ct

Kent Woodlands
Brannon Ct
Nuttree Ln
Palomar Pt
Rossburn Way

Lake Hogan Farms
Bay View Dr
Commons Way
Dairy Ct
Hogan Glen Ct
Long Meadows rd
Shadow Ridge Pl
South Fields C

Mill Race
Mill Race Dr
Mill Run

Parkside
Glenmore Rd
Juliette Ct
Kenilworth Pl
Lonebrook Dr
New Parkside Dr

Roberson Place
Maple Ave
Purple Leaf Pl
Sweet Bay Pl

Silver Creek
Palmyra Pl
San Miguel Pl
San Sophia Dr
Silver Creek Tr
Silver Glade Dr
Sundane Pl
Telluride Tr

Southern Village
Arlen Park Dr
Barksdale Dr
Brookgreen Dr
Calderon Dr
Copperline Dr
Eastgreen Dr
Edgewater Cr
Glade St
Graylyn Dr
Greenview Dr
Highgrove Dr
Kildaire Rd
Meeting St
Newell st
Nolen Ln
Overlake Dr
Overlook Dr
Parkside Cr
Parkview Crescent
Tharrington Dr
Unwin Pl
Westgreen Dr
Westside Dr
Winston Ridge Dr

Sunset Creek
Buckeye Ln
Farm House Dr.
Sunset Creek Cr
Sunset Ridge Ln

Subdivisions with houses constructed before and after 1994.
Subdivision is listed with street names, and the house numbers <= or > June 1994.

Forest Creek	<= June 1994	>= July 1994
Catesby Ln		
Collinson Dr	200, 201, 202, 204, 205, 206, 208, 209, 210, 212, 214, 215	101, 104
Darlin Cr	104, 107	
Gunston Ct	117	
Linneaus Pl	108, 110	
Mendel Dr	111	
Nuttal Pl	102	100, 103, 104, 105
Old Forest Creek Dr	129, 135, 143, 222, 234, 238, 307, 315	
Pinchot Ln	109	
Priestly Creek Dr	118	121

Wexford Place	<= June 1994	>= July 1994
Ellsworth Pl		100-102, 104-106, 108-110
Stratford Dr	100, 104-107, 109-113, 115, 201, 218	101-103, 108, 117, 202-204, 206-217, 219-221
Suffolk Pl	100, 102-111	
Traymore Dr	100	203, 301, 303, 401-405, 407, 501
Wyndham Dr		207, 209, 302-306, 308

Berry Hill	<= June 1994	>= July 1994
Gateridge Pl		100-106
Juniper Ct	100, 102, 104, 106, 108	103, 105, 107
Manor Ridge Dr	607, 701-704, 802-804	200, 202-209, 300, 302-304, 306, 400, 402, 404-406, 408, 500, 503, 505-507, 600-606, 608, 610
Misty Pine Pl		100-103, 105
Oak Spring Ct	102-106	
Orchard Ln	100-104, 107, 200-203, 300-307	

Chesley	<= June 1994	>= July 1994
Arcadia Ln	104, 200, 212	100, 105, 209
Chesley Ln	108, 112	109
Half-Moon Pt	105	
Millbrae Ln	101, 105, 116	100, 104, 113
Muir Ln	all	
Overlook Pt		105
Redbud Ln		120
San Mateo Pl	all	
Sierra Dr	120	104
Tamalpais Pt	all	
Ukiah Ln	105, 205	101, 014, 108, 200, 201, 208
Umbrio Ln		108

Ironwoods	<= June 1994	>= July 1994
Anglese Ct	all	
Birchcrest Pl		116
Bolton Pt	all	
Brighton Ct		100
Burlwood		101
Cardiff Ct		109, 111, 117, 123
Dartmouth Ct	all	
Eastridge Pl	all	
Edgehill Pl		108, 112, 116
Emerywood Pl	all	
Hampshire Pl	all	
Hanover Pl		100
Hardwick Pl		108, 109
Ironwoods Dr		104, 108, 116, 132, 201, 221
Manchester Pl		108
Oldham Pl		117, 118
Thetford Ct		112
Woodleaf Dr	all	

Spring Crest	<= June 1994	>= July 1994
Big Meadows Pl	100, 102-109	
Bonsail Pl		101, 104, 105, 200, 203, 205, 207, 209, 211
Callard Run	102-107, 109	all remaining
Chippoaks Dr	100, 103, 106, 200, 202, 203, 204, 206, 207	all remaining
Green Willow Ct	100-111	
Middlebrook Ct		all
N. Crabtree Knoll	100, 102, 105, 106, 108, 109	104, 107
Orchard Ln		300-306
Pebble Springs Rd	100-109, 202, 204, 301, 303, 304, 305, 306	203, 206, 207, 302, all remaining
Perry Creek Dr	100, 102, 104, 105, 107, 109, 201	111 and all remaining>100
S. Crabtree Knoll	102	104-107, all remaining
Tabscott Ln	100-104	

Appendix H

1999 and 2000

overall	aggregated all:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.79	mean	4.96	5.68	4.91	5.49	6.29	6.85	6.38	5.92	6.29	5.55	5.94	5.09
4.01	stdev	2.94	3.47	3.40	3.64	4.49	4.78	4.71	4.30	4.31	3.65	4.00	3.22
	min	0	0	0	0	0	0	0	0	0	0	0	0
	max	26	26	26	26	26	26	26	26	26	26	26	26
	aggregated 01:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6.21	mean	5.26	5.98	5.19	5.88	6.78	7.47	6.94	6.38	6.75	5.91	6.37	5.43
4.13	stdev	2.99	3.55	3.48	3.75	4.61	4.91	4.86	4.43	4.43	3.74	4.13	3.28
	min	0	0	0	0	0	0	0	0	0	0	0	0
	max	26	26	26	26	26	26	26	26	26	26	26	26
	aggregated 02:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.97	mean	3.67	4.36	3.65	3.75	4.21	4.27	3.87	3.91	4.33	3.94	4.04	3.55
2.77	stdev	2.33	2.75	2.69	2.43	3.16	3.05	2.85	2.89	3.02	2.66	2.69	2.35
	min	0	0	0	0	0	0	0	0	0	0	0	0
	max	25	25	26	21	25	25	25	24	26	26	25	23

1999

overall	1999 all:	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.89	mean	6.67	4.44	5.55	6.22	6.88	7.05	5.61	6.75	5.35	5.42	5.31
4.14	stdev	3.92	3.13	3.81	4.94	4.70	5.03	4.26	4.56	3.44	3.44	3.34
	min	0	0	0	0	0	0	0	0	0	0	0
	max	26	26	26	26	26	26	26	26	26	26	26
	1999 01:	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6.33	mean	7.04	4.71	5.97	6.67	7.48	7.73	6.10	7.27	5.68	5.78	5.71
4.27	stdev	3.97	3.22	3.94	5.09	4.82	5.18	4.42	4.70	3.52	3.53	3.43
	min	0	0	0	0	0	0	0	0	0	0	0
	max	26	26	26	26	26	26	26	26	26	26	26
	1999 02:	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.00	mean	4.95	3.22	3.58	4.19	4.42	4.21	3.51	4.59	3.95	3.92	3.66
2.83	stdev	3.10	2.28	2.29	3.56	3.12	3.01	2.60	3.17	2.64	2.53	2.29
	min	0	0	0	0	0	0	0	0	0	0	0
	max	25	26	21	25	25	25	23	26	26	24	23

2000													
overall	2000 all:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.71	mean	4.96	4.85	5.32	5.43	6.36	6.84	5.68	6.23	5.82	5.76	6.52	4.84
3.89	stdev	2.94	2.79	3.58	3.49	4.04	4.82	4.25	4.32	3.97	3.85	4.49	3.06
	min	0	0	0	0	0	0	0	0	0	0	0	0
	max	26	25	26	26	26	26	26	26	26	26	26	26
	2000 01:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6.11	mean	5.26	5.07	5.62	5.80	6.87	7.47	6.15	6.66	6.21	6.16	7.01	5.14
4.00	stdev	2.99	2.84	3.64	3.58	4.13	4.95	4.38	4.43	4.08	3.95	4.61	3.09
	min	0	0	0	0	0	0	0	0	0	0	0	0
	max	26	25	26	26	26	26	26	26	26	26	26	26
	2000 02:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.94	mean	3.67	3.90	4.01	3.89	4.22	4.18	3.50	4.33	4.02	3.93	4.20	3.42
2.72	stdev	2.33	2.34	2.95	2.53	2.77	3.00	2.61	3.11	2.81	2.68	2.88	2.42
	min	0	0	0	0	0	0	0	0	0	0	0	0
	max	25	22	26	21	25	25	25	24	24	24	25	23

NOTE: consumption in 1000 gallons/month/household

Average outdoor use (by month and total) versus February:

All	ave - all months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Outdoor	2.75	per HH	1.51	0	2.37	2.16	2.82	3.87	3.32	3.24	2.82	2.79	3.47	1.85
Indoor	3.20	per HH	3.44	4.85	2.94	3.27	3.55	2.97	2.36	2.99	3.00	2.98	3.05	2.99
		all HH	8865	0	14396	14912	24318	30801	18695	23178	18286	17892	24921	9449
		all HH (mgd)	0.29	0	0.46	0.50	0.78	1.03	0.60	0.75	0.61	0.58	0.83	0.30
	3.01	stdev	1.66		2.65	2.36	2.83	3.97	3.71	3.60	3.28	3.05	3.77	2.25
		count	5858		6062	6897	8638	7958	5623	7153	6493	6420	7182	5103

where month consumption > February consumption and month and February consumption recorded

01	ave - all months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Outdoor	2.91	per HH	1.56	0	2.50	2.30	3.00	4.15	3.55	3.41	2.96	2.93	3.70	1.90
		% of total	29.6	0.0	44.5	39.6	43.7	55.6	57.6	51.2	47.7	47.6	52.8	36.9
Indoor	3.46	per HH	3.70	5.07	3.12	3.50	3.87	3.32	2.60	3.25	3.24	3.22	3.31	3.24
		all HH	7743	0	12516	13249	22093	28399	17418	20644	16446	16163	22883	8373
		all HH (mgd)	0.25	0	0.40	0.44	0.71	0.95	0.56	0.67	0.55	0.52	0.76	0.27
	3.11	stdev	1.70	0	2.74	2.45	2.92	4.09	3.84	3.74	3.39	3.14	3.90	2.25
		count	4964		4997	5763	7360	6840	4913	6058	5551	5513	6184	4414

02	ave - all months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Outdoor	1.66	per HH	1.26	0	1.77	1.47	1.74	2.15	1.80	2.31	1.95	1.91	2.04	1.56
		% of total	34.2	0.0	44.0	37.7	41.3	51.4	51.4	53.5	48.6	48.5	48.6	45.7
Indoor	2.28	per HH	2.42	3.90	2.24	2.42	2.48	2.03	1.70	2.01	2.06	2.02	2.16	1.86
		all HH	1122	0	1880	1663	2225	2402	1277	2534	1840	1729	2038	1075
		all HH (mgd)	0.04	0	0.06	0.06	0.07	0.08	0.04	0.08	0.06	0.06	0.07	0.03
	2.12	stdev	1.38	0	2.06	1.68	1.92	2.54	2.15	2.53	2.32	2.18	2.36	2.24
		count	894		1065	1134	1278	1118	710	1095	942	907	998	689

NOTE: consumption in 1000 gallons/month/household, unless otherwise noted

			Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Overall:	**1999**	By month for both 01 and 02 units:											
Mean	6.36	Mean	7.01	4.71	5.97	6.65	7.99	7.90	6.15	7.30	5.61	5.74	5.69
St Dev	4.32	St Dev	3.88	3.10	3.94	5.32	5.09	5.26	4.48	4.72	3.51	3.43	3.38

			Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01 units:	**1999**	By month for both 01 and 02 units:											
Mean	6.57	Mean	7.18	4.83	6.18	6.93	8.15	8.20	6.37	7.56	5.79	5.92	5.89
St Dev	4.35	St Dev	3.89	3.15	3.99	5.35	5.08	5.29	4.52	4.74	3.53	3.46	3.41

			Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
02 units:	**1999**	By month for both 01 and 02 units:											
Mean	4.03	Mean	5.10	3.43	3.66	3.43	5.39	4.73	3.78	4.53	3.76	3.81	3.57
St Dev	3.06	St Dev	3.31	2.07	2.23	3.74	4.55	3.68	3.20	3.32	2.62	2.44	2.13

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Overall:	**2000**	By month for both 01 and 02 units:												
Mean	6.11	Mean	5.22	4.97	5.58	5.74	6.86	7.67	6.25	6.69	6.19	6.14	7.00	5.07
St Dev	3.90	St Dev	2.88	2.66	3.43	3.46	4.03	4.89	4.32	4.31	3.96	3.83	4.40	3.01

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01 units:	**2000**	By month for both 01 and 02 units:												
Mean	6.30	Mean	5.36	5.07	5.72	5.93	7.10	7.96	6.45	6.88	6.39	6.36	7.23	5.24
St Dev	3.93	St Dev	2.88	2.65	3.45	3.48	4.03	4.91	4.35	4.35	4.00	3.86	4.44	3.00

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
02 units:	**2000**	By month for both 01 and 02 units:												
Mean	4.00	Mean	3.67	3.83	3.94	3.68	4.26	4.74	3.49	4.64	4.02	3.78	4.60	3.26
St Dev	2.80	St Dev	2.28	2.51	2.62	2.51	3.04	3.50	2.74	3.21	2.67	2.51	2.89	2.41

NOTE: consumption in 1000 gallons/month/household, unless otherwise noted

Full Population w/outliers (13,000 records)

By MONTH:

	Feb-99			Mar-99			Apr-99			May-99		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	1010	9.2	1010	2797	25.2	2797	1908	16.9	1908	2353	20.3	2353
4	3389	30.8	2379	6536	59.0	3739	5051	44.8	3143	5128	44.3	2775
6	5856	53.2	2467	8729	78.7	2193	7562	67.1	2511	6946	60.1	1818
8	7862	71.4	2006	9881	89.1	1152	9169	81.3	1607	8262	71.4	1316
10	9226	83.8	1364	10465	94.4	584	10039	89.0	870	9263	80.1	1001
15	10559	95.9	1333	10935	98.6	470	10845	96.2	806	10581	91.5	1318
20	10861	98.6	302	11043	99.6	108	11081	98.3	236	11118	96.1	537
30	10970	99.6	1744	11078	99.9	613	11218	99.5	1179	11420	98.7	2157
300	11014	100.0	44	11086	100.0	8	11276	100.0	58	11565	100.0	145
Total count:	11014			11086			11276			11565		

	Jan-00			Feb-00			Mar-00			Apr-00			May-00		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	2037	15.8	2037	2032	15.7	2032	2117	17.0	2117	1901	14.9	1901	1396	11.0	1396
4	6294	48.8	4257	6294	48.7	4262	5694	45.8	3577	5616	44.0	3715	4520	35.5	3124
6	9603	74.4	3309	10029	77.5	3735	8683	69.8	2989	8801	69.0	3185	7441	58.5	2921
8	11428	88.5	1825	11657	90.1	1628	10424	83.8	1741	10680	83.8	1879	9513	74.8	2072
10	12216	94.6	788	12374	95.7	717	11357	91.3	933	11611	91.1	931	10847	85.3	1334
15	12775	99.0	559	12828	99.2	454	12136	97.6	779	12432	97.5	821	12161	95.6	1314
20	12862	99.6	87	12905	99.8	77	12308	99.0	172	12627	99.0	195	12488	98.2	327
30	12896	99.9	680	12925	99.9	551	12403	99.7	1046	12723	99.8	1112	12663	99.6	1816
300	12909	100.0	13	12936	100.0	11	12436	100.0	33	12751	100.0	28	12718	100.0	55
Total count:	12909			12936			12436			12751			12718		

Jun-99			Jul-99			Aug-99			Sep-99			Oct-99		
Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
796	10.7	796	1455	12.1	1455	2348	19.4	2348	1308	10.5	1308	1885	14.9	1885
2407	32.4	1611	3990	33.2	2535	5663	46.8	3315	4144	33.1	2836	5692	44.9	3807
3961	53.2	1554	6460	53.7	2470	8254	68.3	2591	6905	55.2	2761	8881	70.1	3189
5123	68.9	1162	8169	67.9	1709	9761	80.7	1507	8871	70.9	1966	10666	84.2	1785
5911	79.5	788	9303	77.3	1134	10570	87.4	809	10090	80.7	1219	11594	91.6	928
6834	91.9	923	10719	89.1	1416	11388	94.2	818	11486	91.9	1396	12358	97.6	764
7168	96.4	334	11327	94.1	608	11733	97.0	345	11966	95.7	480	12523	98.9	165
7365	99.0	1454	11776	97.9	2473	11957	98.9	1387	12299	98.4	2209	12618	99.6	1024
7439	100.0	74	12031	100.0	255	12090	100.0	133	12504	100.0	205	12664	100.0	46
7439			12031			12090			12504			12664		

Jun-00			Jul-00			Aug-00			Sep-00			Oct-00		
Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
1507	12.0	1507	1998	17.2	1998	1547	12.9	1547	1667	14.1	1667	1706	14.6	1706
4378	34.9	2871	5268	45.5	3270	4585	38.1	3038	4867	41.2	3200	4838	41.3	3132
6942	55.4	2564	7802	67.3	2534	7366	61.2	2781	7725	65.3	2858	7717	65.9	2879
8748	69.8	1806	9283	80.1	1481	9169	76.2	1803	9491	80.3	1766	9469	80.8	1752
9948	79.4	1200	10070	86.9	787	10217	84.9	1048	10454	88.4	963	10398	88.8	929
11395	90.9	1447	10937	94.4	867	11297	93.9	1080	11269	95.3	815	11255	96.1	857
11925	95.2	530	11262	97.2	325	11660	96.9	363	11560	97.8	291	11526	98.4	271
12324	98.4	2376	11484	99.1	1414	11908	98.9	1691	11743	99.3	1289	11655	99.5	1257
12530	100.0	206	11588	100.0	104	12035	100.0	127	11821	100.0	78	11715	100.0	60
12530			11588			12035			11821			11715		

Nov-99			Dec-99		
Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
1907	14.9	1907	1950	15.1	1950
5617	43.8	3710	5849	45.3	3899
8812	68.8	3195	9020	69.9	3171
10732	83.8	1920	10942	84.8	1922
11709	91.4	977	11908	92.3	966
12517	97.7	808	12628	97.9	720
12688	99.0	171	12798	99.2	170
12779	99.7	1070	12869	99.8	961
12813	100.0	34	12898	100.0	29
12813			12898		

Nov-00			Dec-00		
Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
1289	11.1	1289	1967	17.1	1967
4032	34.7	2743	5775	50.1	3808
6656	57.2	2624	8658	75.1	2883
8429	72.5	1773	10220	88.7	1562
9595	82.5	1166	10884	94.5	664
10807	92.9	1212	11350	98.5	466
11230	96.5	423	11460	99.5	110
11506	98.9	1911	11507	99.9	623
11632	100.0	126	11522	100.0	15
11632			11523		

Appendix I

Cumulative Distributions

Full Population w/outliers (13,000 records)

By UNIT:

1999 and 2000	For 01 units			For 02 units			For all units		
Water Use Bins	Cumulative frec	Cum %	Frequency	Cumulative frec	Cum %	Frequency	Cumulative frec	Cum %	Frequency
2	26533	11.9	26533	14348	28.3	14348	40881	14.9	40881
4	82420	36.9	55887	33207	65.5	18859	115627	42.2	74746
6	135576	60.7	53156	43233	85.3	10026	178809	65.3	63182
8	170746	76.5	35170	47203	93.1	3970	217949	79.6	39140
10	191157	85.6	20411	48892	96.5	1689	240049	87.6	22100
15	211336	94.6	20179	50156	99.0	1264	261492	95.4	21443
20	217680	97.5	6344	50439	99.5	283	268119	97.9	6627
30	221486	99.2	3806	50600	99.8	161	272086	99.3	3967
Total count:	223288			50686			273974		

year 2000	For 01 units			For 02 units			For all units		
Water Use Bins	Cumulative frec	Cum %	Frequency	Cumulative frec	Cum %	Frequency	Cumulative frec	Cum %	Frequency
2	13675	11.4	13675	7489	27.8	7489	21164	14.4	21164
4	44360	37.1	30685	17801	66.1	10312	62161	42.4	40997
6	74257	62.1	29897	23166	86.0	5365	97423	66.5	35262
8	93335	78.0	19078	25176	93.5	2010	118511	80.8	21088
10	103928	86.9	10593	26043	96.7	867	129971	88.7	11460
15	113975	95.2	10047	26667	99.0	624	140642	95.9	10671
20	117001	97.8	3026	26812	99.6	145	143813	98.1	3171
30	118842	99.3	1841	26895	99.9	83	145737	99.4	1924
Total count:	119661			26933			146594		

year 1999	For 01 units			For 02 units			For all units		
Water Use Bins	Cumulative frec	Cum %	Frequency	Cumulative frec	Cum %	Frequency	Cumulative frec	Cum %	Frequency
2	12858	12.4	12858	6859	28.9	6859	19717	15.5	19717
4	38060	36.7	25202	15406	64.9	8547	53466	42.0	33749
6	61319	59.2	23259	20067	84.5	4661	81386	63.9	27920
8	77411	74.7	16092	22027	92.7	1960	99438	78.1	18052
10	87229	84.2	9818	22849	96.2	822	110078	86.4	10640
15	97361	94.0	10132	23489	98.9	640	120850	94.9	10772
20	100679	97.2	3318	23627	99.5	138	124306	97.6	3456
30	102644	99.1	1965	23705	99.8	78	126349	99.2	2043
Total count:	103627			23753			127380		

Appendix I

Cumulative Distributions

Cleaned Population

After eliminating all consumption > 26

1999 and 2000	For 01 units			For 02 units			For all units		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	26533	12.0	26533	14348	28.4	14348	40881	15.1	40881
4	82420	37.4	55887	33207	65.7	18859	115627	42.6	74746
6	135576	61.5	53156	43233	85.5	10026	178809	65.9	63182
8	170746	77.4	35170	47203	93.3	3970	217949	80.4	39140
10	191157	86.7	20411	48892	96.7	1689	240049	88.5	22100
15	211336	95.8	20179	50156	99.2	1264	261492	96.4	21443
20	217680	98.7	6344	50439	99.7	283	268119	98.9	6627
30	220592	100.0	2912	50566	100.0	127	271158	100.0	3039
Total count:	220592			50566			271158		

for year 2000:	For 01 units			For 02 units			For all units		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	13675	11.5	13675	7489	27.9	7489	21164	14.6	21164
4	44360	37.5	30685	17801	66.2	10312	62161	42.8	40997
6	74257	62.7	29897	23166	86.2	5365	97423	67.0	35262
8	93335	78.8	19078	25176	93.7	2010	118511	81.6	21088
10	103928	87.8	10593	26043	96.9	867	129971	89.4	11460
15	113975	96.2	10047	26667	99.2	624	140642	96.8	10671
20	117001	98.8	3026	26812	99.8	145	143813	99.0	3171
30	118436	100.0	1435	26877	100.0	65	145313	100.0	1500
Total count:	118436			26877			145313		

for year 1999:	For 01 units			For 02 units			For all units		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	12858	12.6	12858	6859	29.0	6859	19717	15.7	19717
4	38060	37.3	25202	15406	65.0	8547	53466	42.5	33749
6	61319	60.0	23259	20067	84.7	4661	81386	64.7	27920
8	77411	75.8	16092	22027	93.0	1960	99438	79.0	18052
10	87229	85.4	9818	22849	96.5	822	110078	87.5	10640
15	97361	95.3	10132	23489	99.2	640	120850	96.0	10772
20	100679	98.6	3318	23627	99.7	138	124306	98.8	3456
30	102156	100.0	1477	23689	100.0	62	125845	100.0	1539
Total count:	102156			23689			125845		

Appendix I **Cumulative Distribution Functions for Sample**

Sample w/outliers removed

By month:

	Feb-99			Mar-99			Apr-99			May-99			Jun-99		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	364	7.8%	364	1130	24.2%	1130	673	14.2%	673	1124	23.5%	1124	255	9.1%	255
4	1330	28.6%	966	2676	57.3%	1546	2004	42.3%	1331	2182	45.7%	1058	745	26.5%	490
6	2411	51.9%	1081	3649	78.2%	973	3118	65.8%	1114	2806	58.7%	624	1296	46.0%	551
8	3290	70.8%	879	4159	89.1%	510	3833	80.9%	715	3312	69.3%	506	1774	63.0%	478
10	3898	83.8%	608	4429	94.9%	270	4193	88.5%	360	3754	78.6%	442	2107	74.8%	333
15	4483	96.4%	585	4616	98.9%	187	4555	96.2%	362	4366	91.4%	612	2520	89.5%	413
20	4599	98.9%	116	4650	99.6%	34	4653	98.2%	98	4595	96.1%	229	2691	95.6%	171
30	4643	99.9%	44	4665	99.9%	15	4721	99.7%	68	4740	99.2%	145	2798	99.4%	107
40	4649	100.0%	6	4668	100.0%	3	4737	100.0%	16	4779	100.0%	39	2816	100.0%	18
Total count:	4649			4668			4737			4779			2816		

	Jan-00			Feb-00			Mar-00			Apr-00			May-00			Jun-00		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	789	14.9%	789	839	15.8%	839	822	16.1%	822	736	14.0%	736	500	9.5%	500	500	9.6%	500
4	2474	46.8%	1685	2609	49.2%	1770	2237	43.9%	1415	2198	41.8%	1462	1629	30.9%	1129	1497	28.7%	997
6	3881	73.4%	1407	4156	78.3%	1547	3525	69.1%	1288	3552	67.6%	1354	2887	54.7%	1258	2509	48.0%	1012
8	4675	88.4%	794	4837	91.2%	681	4240	83.2%	715	4397	83.6%	845	3795	71.9%	908	3365	64.4%	856
10	5013	94.8%	338	5109	96.3%	272	4673	91.7%	433	4788	91.1%	391	4407	83.5%	612	3948	75.6%	583
15	5251	99.3%	238	5279	99.5%	170	4992	97.9%	319	5143	97.8%	355	5047	95.6%	640	4691	89.8%	743
20	5279	99.8%	28	5301	99.9%	22	5059	99.2%	67	5216	99.2%	73	5183	98.2%	136	4958	94.9%	267
30	5289	100.0%	10	5304	100.0%	3	5089	99.8%	30	5253	99.9%	37	5264	99.7%	81	5164	98.9%	206
40	5290	100.0%	1	5306	100.0%	2	5098	100.0%	9	5258	100.0%	5	5278	100.0%	14	5224	100.0%	60
Total count:	5290			5306			5098			5258			5278			5224		

2000	pooled			01 units			02 units		
Water Use Bins	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
2	8118	13.1%	8118	6434	11.4%	6434	1684	32.6%	1684
4	24597	39.8%	16479	21054	37.2%	14620	3543	68.7%	1859
6	39940	64.6%	15343	35462	62.6%	14408	4478	86.8%	935
8	49607	80.3%	9667	44782	79.1%	9320	4825	93.5%	347
10	54755	88.6%	5148	49752	87.8%	4970	5003	97.0%	178
15	59747	96.7%	4992	54630	96.5%	4878	5117	99.2%	114
20	61178	99.0%	1431	56028	98.9%	1398	5150	99.8%	33
30	61800	100.0%	622	56640	100.0%	612	5160	100.0%	10
Total count:	61800			56640			5160		

Jul-99			Aug-99			Sep-99			Oct-99			Nov-99			Dec-99		
Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
516	10.5%	516	803	16.1%	803	472	9.3%	472	786	15.1%	786	740	14.1%	740	711	13.5%	711
1390	28.2%	874	2109	42.2%	1306	1560	30.6%	1088	2284	44.0%	1498	2165	41.2%	1425	2206	41.8%	1495
2393	48.5%	1003	3222	64.5%	1113	2633	51.7%	1073	3610	69.5%	1326	3516	67.0%	1351	3598	68.1%	1392
3129	63.5%	736	3922	78.5%	700	3506	68.9%	873	4363	84.0%	753	4385	83.5%	869	4434	84.0%	836
3651	74.1%	522	4316	86.4%	394	4040	79.4%	534	4754	91.6%	391	4790	91.2%	405	4857	92.0%	423
4349	88.2%	698	4701	94.2%	385	4676	91.8%	636	5079	97.8%	325	5147	98.0%	357	5177	98.0%	320
4649	94.3%	300	4851	97.2%	150	4884	95.9%	208	5146	99.1%	67	5212	99.3%	65	5246	99.3%	69
4857	98.5%	208	4961	99.4%	110	5033	98.9%	149	5184	99.9%	38	5243	99.8%	31	5276	99.9%	30
4929	100.0%	72	4993	100.0%	32	5091	100.0%	58	5191	100.0%	7	5251	100.0%	8	5281	100.0%	5
4929			4993			5091			5191			5251			5281		

Jul-00			Aug-00			Sep-00			Oct-00			Nov-00			Dec-99		
Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency	Cumulative freq	Cum %	Frequency
728	14.8%	728	569	10.9%	569	669	12.8%	669	675	13.0%	675	489	9.5%	489	802	15.6%	802
2009	40.8%	1281	1807	34.7%	1238	2015	38.7%	1346	1975	38.1%	1300	1641	31.8%	1152	2506	48.6%	1704
3106	63.1%	1097	3046	58.5%	1239	3294	63.2%	1279	3299	63.6%	1324	2824	54.7%	1183	3861	74.9%	1355
3837	77.9%	731	3905	75.0%	859	4136	79.4%	842	4140	79.8%	841	3692	71.5%	868	4588	89.0%	727
4191	85.1%	354	4367	83.9%	462	4585	88.0%	449	4566	88.0%	426	4229	81.9%	537	4879	94.7%	291
4626	93.9%	435	4876	93.7%	509	4966	95.4%	381	4988	96.1%	422	4797	92.9%	568	5091	98.8%	212
4775	96.9%	149	5053	97.1%	177	5111	98.1%	145	5108	98.5%	120	5003	96.9%	206	5132	99.6%	41
4896	99.4%	121	5174	99.4%	121	5189	99.6%	78	5169	99.6%	61	5123	99.2%	120	5150	99.9%	18
4926	100.0%	30	5204	100.0%	30	5208	100.0%	19	5188	100.0%	19	5163	100.0%	40	5153	100.0%	3
4926			5204			5208			5188			5163			5153		

```
********************************************************************************
8:08 PM 4/15/01
. set mem 100m
(102400k)
. use "D:\alldata.dta", clear
. drop address lastname firstnam billaddr billingt cooldegr heatdegr ownrlast ownfirst
owner2 property zip x_coord y_coord map block lot mnthsold daysold building descript
bldgtype class style exterior attic found heat ac post1994
. save "D:\regress.dta"
file D:\regress.dta saved
. iis customer
. sort unit
. by  unit: sum wateruse
-> unit=        1
Variable |     Obs        Mean   Std. Dev.        Min         Max
---------+-----------------------------------------------------
wateruse |  105746    6.796787   5.739967           0         301
-> unit=        2
Variable |     Obs        Mean   Std. Dev.        Min         Max
---------+-----------------------------------------------------
wateruse |    9557     4.08036   3.620934           0         126

. xtsum
Variable         |      Mean   Std. Dev.       Min        Max |    Observations
-----------------+--------------------------------------------+----------------
customer overall |  108722.7   5766.356     100048     122101 |     N =  115303
         between |             6009.829     100048     122101 |     n =    5321
         within  |                    0   108722.7   108722.7 | T-bar = 21.6694
                 |                                            |
month    overall |  12.31343   6.547395          1         23 |     N =  115303
         between |              1.08539          7       17.5 |     n =    5321
         within  |             6.481983  -.6277501   25.71343 | T-bar = 21.6694
                 |                                            |
wateruse overall |  6.571633   5.644811          0        301 |     N =  115303
         between |             3.829397   .9130435         39 |     n =    5321
         within  |              4.13859  -23.42837   277.8444 | T-bar = 21.6694
                 |                                            |
precip   overall |  4.197601   4.604751        .26      24.01 |     N =  115303
         between |             .1969373   2.708462   5.161333 |     n =    5321
         within  |              4.60172  -.3377327   24.28602 | T-bar = 21.6694
                 |                                            |
avetemp  overall |   59.5373   13.66107      36.02      80.06 |     N =  115303
         between |             .7607909   54.65267   63.37333 |     n =    5321
         within  |             13.64365   32.18397   84.94463 | T-bar = 21.6694
                 |                                            |
area     overall |  21230.57   23311.43        813     680773 |     N =  115303
         between |             23716.35        813     680773 |     n =    5321
         within  |             14.09536   20956.96   25881.96 | T-bar = 21.6694
                 |                                            |
houseval overall |  178125.6   99104.69        341    1085710 |     N =  115303
         between |             99550.21        341    1085710 |     n =    5321
         within  |             214.2208   173967.3   248817.3 | T-bar = 21.6694
yrbuilt  overall |  1977.658   17.17518       1902       2000 |     N =   26894
         between |             17.20541       1902       2000 |     n =    1229
         within  |                    0   1977.658   1977.658 | T-bar = 21.8828
                 |                                            |
c1994    overall |  .1952108   .3963703          0          1 |     N =   26894
         between |             .4002849          0          1 |     n =    1229
         within  |                    0   .1952108   .1952108 | T-bar = 21.8828
                 |                                            |
bathroom overall |  2.210132   .7779922          1          7 |     N =   20944
         between |             .7776808          1          7 |     n =     959
         within  |                    0   2.210132   2.210132 | T-bar = 21.8394
                 |                                            |
jan      overall |  .0459658    .209412          0          1 |     N =  115303
         between |             .0069695          0   .0833333 |     n =    5321
         within  |             .2093269  -.0373675   1.002488 | T-bar = 21.6694
                 |                                            |
feb      overall |  .0864592   .2810421          0          1 |     N =  115303
         between |             .0124053          0   .1538462 |     n =    5321
         within  |               .28081   -.067387   1.041005 | T-bar = 21.6694
```

```
         |                                                |
mar      overall |  .0851149   .2790538          0          1 |     N =  115303
         between |             .0149154          0   .1538462 |     n =    5321
         within  |             .2787238  -.0687313    1.03966 | T-bar = 21.6694
                 |                                            |
apr      overall |  .0869448   .2817554          0          1 |     N =  115303
         between |             .0111578          0   .1428571 |     n =    5321
         within  |             .2815705  -.0559123    1.04149 | T-bar = 21.6694
                 |                                            |
may      overall |  .0879335   .2831994          0          1 |     N =  115303
         between |             .0099092          0   .1428571 |     n =    5321
         within  |             .2830603  -.0549236   1.040314 | T-bar = 21.6694
                 |                                            |
jun      overall |  .0703798   .2557871          0          1 |     N =  115303
         between |             .0208766          0   .1428571 |     n =    5321
         within  |             .2549426  -.0724774   1.024925 | T-bar = 21.6694
                 |                                            |
jul      overall |  .0863984   .2809527          0          1 |     N =  115303
         between |             .0130814          0   .1538462 |     n =    5321
         within  |             .2806899  -.0674477   1.040944 | T-bar = 21.6694
                 |                                            |
aug      overall |  .0889916   .2847329          0          1 |     N =  115303
         between |             .0094173          0   .1666667 |     n =    5321
         within  |              .284608  -.0776751   1.043537 | T-bar = 21.6694
                 |                                            |
sep      overall |  .0899543   .2861175          0          1 |     N =  115303
         between |             .0097489          0   .1666667 |     n =    5321
         within  |             .2859863  -.0767124     1.0445 | T-bar = 21.6694
                 |                                            |
oct      overall |  .0903446    .286676          0          1 |     N =  115303
         between |             .0107689          0   .1666667 |     n =    5321
         within  |             .2865186  -.0763221    1.04489 | T-bar = 21.6694
                 |                                            |
nov      overall |  .0907435   .2872453          0          1 |     N =  115303
         between |             .0116142    .047619   .1666667 |     n =    5321
         within  |              .287066  -.0759231   1.043124 | T-bar = 21.6694
                 |                                            |
dec      overall |  .0907695   .2872823          0          1 |     N =  115303
         between |               .01347          0   .1666667 |     n =    5321
         within  |              .287045  -.0758971   1.045315 | T-bar = 21.6694
                 |                                            |
year     overall |  .5426919   .4981762          0          1 |     N =  115303
         between |             .0739475   .1538462          1 |     n =    5321
         within  |             .4943115  -.3803851   1.388846 | T-bar = 21.6694
                 |                                            |
d_unit   overall |   .082886    .275711          0          1 |     N =  115303
         between |             .2796658          0          1 |     n =    5321
         within  |                    0    .082886    .082886 | T-bar = 21.6694
                 |                                            |
hous1000 overall |  178.1256   99.10469       .341    1085.71 |     N =  115303
         between |             99.55021       .341    1085.71 |     n =    5321
         within  |             .2142208   173.9673   248.8173 | T-bar = 21.6694
                 |                                            |
constr94 overall |  .4131883   .4924116          0          1 |     N =   44873
         between |             .4947503          0          1 |     n =    2087
         within  |                    0   .4131883   .4131883 | T-bar = 21.5012

*****************************************************************
04/16/01
. use "D:\regress.dta", clear
. sort unit
. xttab unit
                  Overall             Between            Within
    unit |    Freq.  Percent      Freq.  Percent        Percent
---------+-----------------------------------------------------
       1 |   105746    91.71       4866    91.45         100.00
       2 |     9557     8.29        455     8.55         100.00
---------+-----------------------------------------------------
   Total |   115303   100.00       5321   100.00         100.00
                                 (n = 5321)
```

. xttab c1994

c1994	Overall Freq.	Overall Percent	Between Freq.	Between Percent	Within Percent
0	21644	80.48	983	79.98	100.00
1	5250	19.52	246	20.02	100.00
Total	26894	100.00	1229	100.00	100.00
			(n = 1229)		

. xttab yrbuilt

yrbuilt	Overall Freq.	Overall Percent	Between Freq.	Between Percent	Within Percent
1902	46	0.17	2	0.16	100.00
1912	46	0.17	2	0.16	100.00
1920	20	0.07	1	0.08	100.00
1921	43	0.16	2	0.16	100.00
1922	67	0.25	3	0.24	100.00
1924	23	0.09	1	0.08	100.00
1925	21	0.08	1	0.08	100.00
1926	23	0.09	1	0.08	100.00
1930	23	0.09	1	0.08	100.00
1932	232	0.86	11	0.90	100.00
1935	21	0.08	1	0.08	100.00
1937	41	0.15	2	0.16	100.00
1938	23	0.09	1	0.08	100.00
1939	69	0.26	3	0.24	100.00
1940	46	0.17	2	0.16	100.00
1942	406	1.51	18	1.46	100.00
1944	23	0.09	1	0.08	100.00
1945	23	0.09	1	0.08	100.00
1946	22	0.08	1	0.08	100.00
1947	322	1.20	15	1.22	100.00
1948	46	0.17	2	0.16	100.00
1949	88	0.33	4	0.33	100.00
1950	145	0.54	7	0.57	100.00
1951	23	0.09	1	0.08	100.00
1952	724	2.69	33	2.69	100.00
1953	23	0.09	1	0.08	100.00
1954	138	0.51	6	0.49	100.00
1955	182	0.68	8	0.65	100.00
1956	68	0.25	3	0.24	100.00
1957	866	3.22	40	3.25	100.00
1958	128	0.48	6	0.49	100.00
1959	67	0.25	3	0.24	100.00
1960	246	0.91	11	0.90	100.00
1961	243	0.90	11	0.90	100.00
1962	1034	3.84	46	3.74	100.00
1963	67	0.25	3	0.24	100.00
1964	526	1.96	24	1.95	100.00
1965	398	1.48	18	1.46	100.00
1966	640	2.38	29	2.36	100.00
1967	777	2.89	35	2.85	100.00
1968	197	0.73	9	0.73	100.00
1969	216	0.80	10	0.81	100.00
1970	337	1.25	15	1.22	100.00
1971	623	2.32	28	2.28	100.00
1972	135	0.50	6	0.49	100.00
1973	249	0.93	11	0.90	100.00
1974	514	1.91	23	1.87	100.00
1975	577	2.15	26	2.12	100.00
1976	298	1.11	14	1.14	100.00
1977	313	1.16	14	1.14	100.00
1978	274	1.02	12	0.98	100.00
1979	349	1.30	16	1.30	100.00
1980	334	1.24	15	1.22	100.00
1981	472	1.76	21	1.71	100.00
1982	206	0.77	10	0.81	100.00
1983	637	2.37	29	2.36	100.00
1984	1279	4.76	59	4.80	100.00

```
      1985 |      458      1.70           21      1.71         100.00
      1986 |      600      2.23           27      2.20         100.00
      1987 |      770      2.86           35      2.85         100.00
      1988 |      856      3.18           39      3.17         100.00
      1989 |     1051      3.91           48      3.91         100.00
      1990 |      676      2.51           31      2.52         100.00
      1991 |      705      2.62           32      2.60         100.00
      1992 |      986      3.67           45      3.66         100.00
      1993 |      563      2.09           26      2.12         100.00
      1994 |      814      3.03           37      3.01         100.00
      1995 |      762      2.83           35      2.85         100.00
      1996 |      736      2.74           33      2.69         100.00
      1997 |      991      3.68           46      3.74         100.00
      1998 |     1309      4.87           61      4.96         100.00
      1999 |      530      1.97           29      2.36         100.00
      2000 |      108      0.40            5      0.41         100.00
-----------+-----------------------------------------------------------
     Total |    26894    100.00         1229    100.00         100.00
                                   (n = 1229)

. xttab bathroom
                  Overall             Between             Within
  bathroom |    Freq.  Percent      Freq.  Percent        Percent
-----------+-----------------------------------------------------------
         1 |     3071     14.66         137     14.29         100.00
       1.5 |     1540      7.35          72      7.51         100.00
         2 |     6798     32.46         310     32.33         100.00
       2.5 |     5498     26.25         253     26.38         100.00
         3 |     2275     10.86         105     10.95         100.00
       3.5 |     1108      5.29          52      5.42         100.00
         4 |      420      2.01          19      1.98         100.00
       4.5 |      102      0.49           5      0.52         100.00
         5 |       88      0.42           4      0.42         100.00
         6 |       23      0.11           1      0.10         100.00
         7 |       21      0.10           1      0.10         100.00
-----------+-----------------------------------------------------------
     Total |    20944    100.00         959    100.00         100.00
                                   (n = 959)

. xttab constr94
                  Overall             Between             Within
  constr94 |    Freq.  Percent      Freq.  Percent        Percent
-----------+-----------------------------------------------------------
         0 |    26332     58.68        1196     57.31         100.00
         1 |    18541     41.32         891     42.69         100.00
-----------+-----------------------------------------------------------
     Total |    44873    100.00        2087    100.00         100.00
                                   (n = 2087)

***************************************************************************
11:11 AM 4/19/01

. use "D:\regress.dta", clear
. gen lnwater = ln( wateruse)
(255 missing values generated)
. gen lnprecip = ln( precip)
. gen lntemp = ln( avetemp)
. gen lnarea = ln( area)
. gen lnhouse = ln( hous1000)
. gen lnbath = ln( bathroom)
(94359 missing values generated)
. gen lnbedrms = ln( bedrooms)
(94943 missing values generated)
. gen lnrooms = ln( norooms)
(94804 missing values generated)

. save "D:\regress.dta", replace
file D:\regress.dta saved
. gen area2 = area^2
```

```
******************************************************************************
04/23/01
. use "D:\regress.dta", clear
. *rescale the area so that it is in units of 1000s of sq ft
. gen area1000 =  area/1000
. *generate a squared term for the area in 1000s of sq ft
. gen area2000 =  area1000^2

**************************************************************************
2:28 PM 5/10/01
. set mem 200m
(204800k)
. use "D:\regress.dta", clear
. sort jan
. by  jan: sum wateruse
-> jan=        0
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  110003     6.63521   5.731132          0        301

-> jan=        1
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |    5300    5.252075    3.10796          0         54

. sort feb
. by feb: sum wateruse
-> feb=        0
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  105334    6.627461    5.78244          0        301

-> feb=        1
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |    9969    5.981743    3.85578          0        102

. sort mar
. by  mar: sum wateruse
-> mar=        0
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  105489    6.693826     5.7503          0        301

-> mar=        1
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |    9814    5.258203     4.1303          0        111

. sort apr
. by  apr: sum wateruse
-> apr=        0
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  105278    6.625981    5.75071          0        301

-> apr=        1
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |   10025    6.000898   4.340057          0         69

. sort may
. by  may: sum wateruse
-> may=        0
Variable |     Obs        Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  105164    6.517554   5.594862          0        301
```

```
-> may=         1
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |   10139     7.132557   6.111106          0        117

. sort jun
. by  jun: sum wateruse
-> jun=         0
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  107188     6.416474   5.461894          0        301

-> jun=         1
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |    8115     8.621072   7.361169          0        103

. sort jul
. by  jul: sum wateruse
-> jul=         0
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  105341     6.447603   5.421277          0        301

-> jul=         1
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |    9962     7.883156   7.492901          0        113

. sort aug
. by  aug: sum wateruse
-> aug=         0
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  105042      6.53491   5.549397          0        301

-> aug=         1
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |   10261     6.947568   6.530449          0        172

. sort sep
. by  sep: sum wateruse
-> sep=         0
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  104931     6.501015   5.565955          0        301

-> sep=         1
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |   10372     7.286059   6.344315          0        131

. sort oct
. by  oct: sum wateruse
-> oct=         0
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  104886      6.61993   5.719243          0        301

-> oct=         1
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |   10417     6.085341   4.805162          0        126

. sort nov
. by  nov: sum wateruse
-> nov=         0
Variable |     Obs         Mean   Std. Dev.       Min        Max
---------+-----------------------------------------------------
wateruse |  104840     6.558728   5.664215          0        301
```

```
-> nov=          1
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |    10463      6.700946    5.445137          0         164

. sort dec
. by  dec: sum wateruse
-> dec=          0
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |   104837      6.680876    5.723484          0         172

-> dec=          1
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |    10466      5.477355    4.646522          0         301

. sort year
. by  year: sum wateruse
-> year=          0
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |    52729      6.724649    5.813602          0         126

-> year=          1
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |    62574      6.442692    5.495295          0         301

. sort c1994
. by  c1994: sum wateruse
-> c1994=          0
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |    21644       5.97981    5.044918          0         142

-> c1994=          1
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |     5250      6.746667    5.669924          0         117

-> c1994=          .
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |    88409      6.706127    5.771652          0         301

. sort bathroom
. by  bathroom: sum wateruse
-> bathroom=          1
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |     3071      3.981765    3.118453          0          57

-> bathroom=        1.5
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |     1540      5.268831    5.140059          0         126

-> bathroom=          2
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |     6798      5.257723    3.685409          0          52

-> bathroom=        2.5
Variable |      Obs          Mean    Std. Dev.        Min         Max
---------+-----------------------------------------------------------
wateruse |     5498      6.451073    5.178835          0         142
```

```
-> bathroom=        3
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |    2275    6.946813    4.66374          0          75

-> bathroom=      3.5
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |    1108    8.207581    5.573866         0          67

-> bathroom=        4
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |     420    7.797619    4.383141         0          31

-> bathroom=      4.5
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |     102    7.833333    5.050406         1          23

-> bathroom=        5
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |      88    18.38636    17.66575         2         117

-> bathroom=        6
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |      23    30.08696    25.67792         4          86

-> bathroom=        7
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |      21    10.47619    4.202607         3          19

-> bathroom=        .
Variable |     Obs          Mean   Std. Dev.       Min         Max
---------+-----------------------------------------------------
wateruse |   94359    6.726173    5.787497         0         301

*************************************************************************
2:36 PM 6/15/01
. set mem 200m
(204800k)
. use "D:\regress.dta", clear
. gen y1999 = (year==0)
. drop  y1999
. drop unit township yearsold year lnprecip lntemp lnarea lnhouse lnbath lnbedrms lnrooms
temp60
. save "D:\regress2000.dta"
file D:\regress2000.dta saved
. clear
. insheet using d:\weather.txt, tab names
(5 vars, 12 obs)
. save "D:\weather.dta"
file D:\weather.dta saved
. sort month
. save "D:\weather.dta", replace
file D:\weather.dta saved
. use "D:\regress2000.dta", clear
. sort month
. merge month using d:\weather
. tab _merge

     _merge |      Freq.     Percent        Cum.
------------+-----------------------------------
          1 |      52729       45.73       45.73
          3 |      62574       54.27      100.00
------------+-----------------------------------
      Total |     115303      100.00
```

```
. keep if month >11
(52729 observations deleted)
. label variable  lnwater "Ln Water Use"
. label variable area2 "Area squared"
. label variable area2000 "Area (in 1000s) squared"
. label variable area1000 "Area (in 1000s)"
. label variable raindays "Number of days of precipitation per month"
. label variable d_unit "Dummy for Housing type 0=SF, 1=MF)
. label variable hous1000 "House value (in 1000s):
. label variable hous1000 "House value (in 1000s)"
. label variable constr94 "0 if constructed before 1994, 1 if after"
. gen lnbath = ln( bathroom)
(51326 missing values generated)
. gen lnhouse =ln( hous1000)
. label variable  lnhouse "Ln House value in 1000s"
. gen lnarea = ln( area1000)
. label variable lnarea "Ln Area in 1000s"
. gen lnarea2 = ln( area2000)
. label variable lnarea2 "Ln Area Squared in 1000s"

. *Functional form:  boxcox test
. boxcox  wateruse raindays avetemp bathroom d_unit hous1000 constr94 area1000 area2000
feb mar apr may jun jul aug sep oct nov dec if wateruse>0
(note: iterations performed using zero =.001)

  Iteration       Lambda          Zero        Variance          LL
  -----------------------------------------------------------------------
        0         1.0000  -11824.06554    17.7670011  -16012.41306
        1         0.3584   -2645.84248    8.02759606  -11591.25565
        2         0.1158    -198.29880    7.53806106  -11241.10520
        3         0.0948      -1.54509    7.53389105  -11238.02583
        4         0.0947      -0.00390    7.53388044  -11238.01798
        5         0.0947      -0.00001    7.53388041  -11238.01797
  -----------------------------------------------------------------------

Transform:  (wateruse^L-1)/L

                  L        [95% Conf. Interval]     Log Likelihood
             ------------------------------------------------------
               0.0947        (not calculated)            -11238.018

     Test:  L == -1      chi2(1) =   9594.04     Pr>chi2 =  0.0000
            L ==  0      chi2(1) =     90.85     Pr>chi2 =  0.0000
            L ==  1      chi2(1) =   9312.31     Pr>chi2 =  0.0000

(type regress without arguments for regression estimates conditional on L)

. regress

  Source |       SS       df       MS                  Number of obs =   11130
---------+------------------------------               F( 17, 11112) =  153.30
   Model |  1233.46607    17  72.5568278               Prob > F      =  0.0000
Residual |  5259.24677 11112  .473294346               R-squared     =  0.1900
---------+------------------------------               Adj R-squared =  0.1887
   Total |  6492.71285 11129  .583404874               Root MSE      =  .68796

------------------------------------------------------------------------------
 _boxcox |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
raindays |  -.0056663   .0021175     -2.676   0.007      -.0098169   -.0015156
 avetemp |   .0021587   .0008826      2.446   0.014       .0004288    .0038887
bathroom |   .1339961   .0131291     10.206   0.000       .1082607    .1597314
  d_unit |  -.3435873   .0253519    -13.553   0.000      -.3932815    -.293893
hous1000 |    .002154   .0001241     17.360   0.000       .0019108    .0023972
constr94 |  -.0288059   .0212247     -1.357   0.175      -.0704102    .0127983
area1000 |   .0008804   .0007538      1.168   0.243      -.0005973     .002358
area2000 |  -.0000145   4.67e-06     -3.097   0.002      -.0000236   -5.31e-06
     feb |  -.1107836   .0296902     -3.731   0.000      -.1689817   -.0525855
     mar |  -.0550215   .0282553     -1.947   0.052      -.1104069    .0003638
     apr |    .042681   .0280444      1.522   0.128       -.012291     .097653
     may |   .1386387   .0294104      4.714   0.000       .0809892    .1962882
```

jun	.2813072	.0312746	8.995	0.000	.2200035	.3426109
jul	(dropped)					
aug	.132624	.0313683	4.228	0.000	.0711367	.1941113
sep	.0561299	.0300219	1.870	0.062	-.0027183	.1149782
oct	(dropped)					
nov	.2485435	.02761	9.002	0.000	.1944231	.302664
dec	-.0825742	.0334272	-2.470	0.014	-.1480975	-.0170509
_cons	.9537383	.0656268	14.533	0.000	.8250982	1.082379

```
. *Multicollinearity testing
. quietly xtreg wateruse raindays avetemp bathroom d_unit hous1000 constr94 area1000
area2000 feb mar apr may jun jul aug sep oct nov dec
. corr wateruse raindays avetemp bathroom d_unit hous1000 constr94 area1000 area2000 feb
mar apr may jun jul aug sep oct nov dec
(obs=11164)
```

	wateruse	raindays	avetemp	bathroom	d_unit	hous1000	constr94
wateruse	1.0000						
raindays	0.0088	1.0000					
avetemp	0.1294	0.0077	1.0000				
bathroom	0.2903	-0.0001	-0.0003	1.0000			
d_unit	-0.1361	0.0003	-0.0043	-0.0945	1.0000		
hous1000	0.3287	0.0012	0.0034	0.7639	-0.1660	1.0000	
constr94	0.1194	-0.0012	-0.0003	0.3059	-0.1040	0.3910	1.0000
area1000	0.1036	0.0006	0.0025	0.2448	-0.2767	0.2960	-0.1044
area2000	0.0186	-0.0001	0.0005	0.1026	-0.0870	0.1366	-0.0468
feb	-0.0732	-0.1982	-0.2938	0.0004	0.0036	-0.0004	0.0011
mar	-0.0340	-0.2607	-0.1057	0.0027	-0.0065	0.0007	0.0033
apr	-0.0262	0.3432	-0.0382	-0.0002	0.0014	-0.0003	0.0000
may	0.0396	-0.4001	0.2388	0.0002	0.0022	0.0000	0.0014
jun	0.1100	0.0734	0.3840	0.0002	0.0031	0.0000	0.0011
jul	0.0079	0.2002	0.3607	0.0008	-0.0128	0.0061	-0.0029
aug	0.0471	0.1405	0.3590	-0.0008	0.0016	0.0003	-0.0006
sep	0.0007	0.2754	0.2195	-0.0010	0.0016	-0.0009	-0.0006
oct	-0.0040	-0.5987	0.0406	-0.0014	0.0000	-0.0013	-0.0006
nov	0.0570	0.1396	-0.2399	-0.0009	0.0004	-0.0017	-0.0009
dec	-0.0663	-0.1278	-0.4733	-0.0004	0.0012	-0.0017	-0.0027

	area1000	area2000	feb	mar	apr	may	jun
area1000	1.0000						
area2000	0.8463	1.0000					
feb	-0.0018	-0.0007	1.0000				
mar	-0.0006	-0.0004	-0.0912	1.0000			
apr	-0.0015	-0.0008	-0.0925	-0.0905	1.0000		
may	-0.0007	-0.0002	-0.0926	-0.0907	-0.0920	1.0000	
jun	-0.0010	-0.0003	-0.0927	-0.0908	-0.0921	-0.0923	1.0000
jul	0.0070	0.0016	-0.0889	-0.0871	-0.0883	-0.0885	-0.0886
aug	-0.0003	0.0001	-0.0924	-0.0904	-0.0917	-0.0919	-0.0920
sep	-0.0003	-0.0001	-0.0924	-0.0904	-0.0917	-0.0919	-0.0920
oct	0.0001	0.0003	-0.0920	-0.0901	-0.0914	-0.0915	-0.0916
nov	0.0001	0.0004	-0.0918	-0.0899	-0.0911	-0.0913	-0.0914
dec	0.0009	0.0008	-0.0914	-0.0895	-0.0908	-0.0909	-0.0910

	jul	aug	sep	oct	nov	dec
jul	1.0000					
aug	-0.0882	1.0000				
sep	-0.0882	-0.0916	1.0000			
oct	-0.0879	-0.0912	-0.0912	1.0000		
nov	-0.0876	-0.0910	-0.0910	-0.0907	1.0000	
dec	-0.0873	-0.0907	-0.0907	-0.0903	-0.0901	1.0000

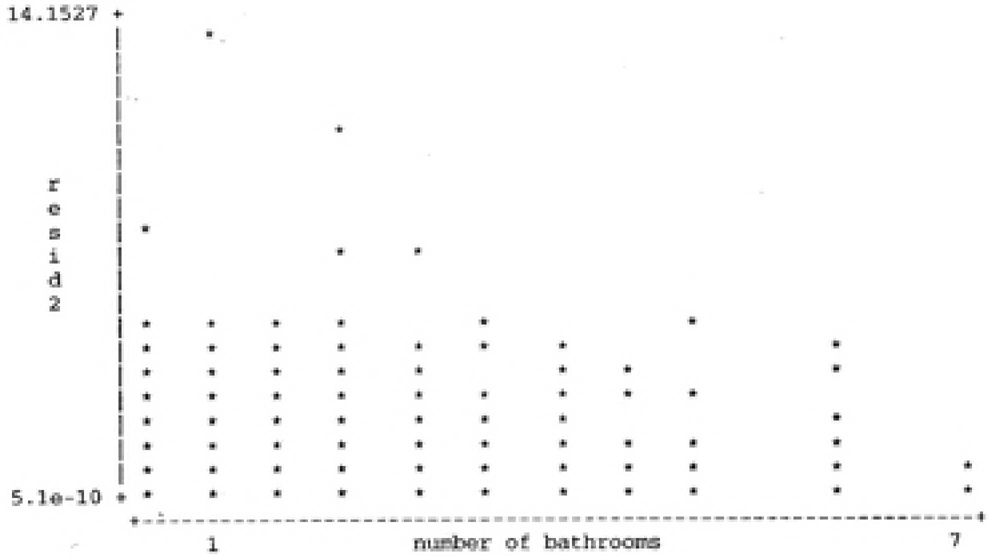
```
. corr, _coef

         | raindays  avetemp bathroom   d_unit hous1000 constr94 area1000
---------+---------------------------------------------------------------
raindays |   1.0000
 avetemp |   0.5062   1.0000
bathroom |  -0.4726  -0.6443   1.0000
  d_unit |  -0.1801  -0.2448  -0.0870   1.0000
hous1000 |   0.1738   0.2367  -0.6821   0.0154   1.0000
constr94 |  -0.0269  -0.0361  -0.0526   0.1826  -0.3098   1.0000
area1000 |  -0.2268  -0.3101  -0.0945   0.3972  -0.2400   0.3442   1.0000
area2000 |   0.1916   0.2617   0.0804  -0.3131   0.1583  -0.2472  -0.8707
     feb |   0.1326   0.1166  -0.1783  -0.0682   0.0654  -0.0101  -0.0852
     mar |   0.0335  -0.1966   0.0141   0.0083  -0.0049   0.0004   0.0083
     apr |  -0.6085  -0.5489   0.3528   0.1344  -0.1299   0.0201   0.1696
     may |  -0.1053  -0.6090   0.2852   0.1079  -0.1048   0.0156   0.1372
     jun |  -0.5162  -0.8077   0.4904   0.1860  -0.1803   0.0274   0.2357
     jul |  -0.5790  -0.8035   0.5040   0.1926  -0.1862   0.0292   0.2413
     aug |  -0.5498  -0.8014   0.4941   0.1877  -0.1819   0.0281   0.2374
     sep |  -0.6089  -0.7411   0.4692   0.1784  -0.1725   0.0266   0.2253
     oct |        .        .        .        .        .        .        .
     nov |  -0.3320  -0.1897   0.0854   0.0330  -0.0313   0.0052   0.0407
     dec |   0.2116   0.4041  -0.3424  -0.1298   0.1259  -0.0185  -0.1650
   _cons |        .        .        .        .        .        .        .

         | area2000      feb      mar      apr      may      jun      jul
---------+---------------------------------------------------------------
area2000 |   1.0000
     feb |   0.0720   1.0000
     mar |  -0.0068   0.2966   1.0000
     apr |  -0.1431   0.1402   0.2776   1.0000
     may |  -0.1158   0.1910   0.3895   0.4251   1.0000
     jun |  -0.1990   0.0794   0.3173   0.6290   0.6034   1.0000
     jul |  -0.2036   0.0634   0.2954   0.6481   0.5754   0.7752   1.0000
     aug |  -0.2004   0.0752   0.3083   0.6409   0.5885   0.7746   0.7780
     sep |  -0.1902   0.0861   0.2927   0.6571   0.5370   0.7462   0.7573
     oct |        .        .        .        .        .        .        .
     nov |  -0.0345   0.2535   0.2835   0.4328   0.2796   0.3612   0.3716
     dec |   0.1392   0.3370   0.2008  -0.0085  -0.0232  -0.1591  -0.1673
   _cons |        .        .        .        .        .        .        .

         |      aug      sep      oct      nov      dec    _cons
---------+------------------------------------------------------
     aug |   1.0000
     sep |   0.7524   1.0000
     oct |        .        .        .
     nov |   0.3708   0.3999        .   1.0000
     dec |  -0.1579  -0.1227        .   0.1954   1.0000
   _cons |        .        .        .        .        .        .

. save "D:\regress2000.dta", replace
file D:\regress2000.dta saved

******************************************************************************
2:55 PM 6/20/01
. *using full data set
. use "D:\regress.dta", clear
. label variable  lnwater "Ln Water Use"
. label variable area2 "Area squared"
. label variable area2000 "Area (in 1000s) squared"
. label variable area1000 "Area (in 1000s)"
. label variable d_unit "Dummy for Housing type 0=SF, 1=MF)
. label variable hous1000 "House value (in 1000s)"
. label variable constr94 "0 if constructed before 1994, 1 if after"
. label variable year "0 if 1999, 1 if 2000"
. save "D:\regress.dta", replace
file D:\regress.dta saved
. *create interaction term for house value and number of bathrooms
. gen housbath =  hous1000* bathroom
(94359 missing values generated)
. label variable housbath "Interaction term for house value and bathrooms"
```

```
. *Panel regression with interaction term
. xtreg wateruse bathroom hous1000 housbath area1000 area2000 d_unit constr94 a
> vetemp precip feb mar apr may jun jul aug sep oct nov dec year

Random-effects GLS regression                   Number of obs      =     20785
Group variable (i) : customer                   Number of groups   =       952

R-sq:  within  = 0.0523                         Obs per group: min =        12
       between = 0.2536                                        avg =      21.8
       overall = 0.1468                                        max =        23

Random effects u_i ~ Gaussian                   Wald chi2(21)      =   1419.42
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
wateruse |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
bathroom |   .2662285   .2233439     1.192   0.233      -.1715175    .7039744
hous1000 |   .0083893   .0033471     2.506   0.012        .001829    .0149495
housbath |   .0018889    .000941     2.007   0.045       .0000447    .0037331
area1000 |   .0148595   .0107198     1.386   0.166       -.006151      .03587
area2000 |  -.0001219   .0000668    -1.824   0.068      -.0002529    9.11e-06
  d_unit |   -1.20262   .3554195    -3.384   0.001       -1.89923    -.506011
constr94 |  -.3125467   .3005124    -1.040   0.298      -.9015401    .2764467
 avetemp |  -.0147984   .0113528    -1.304   0.192      -.0370494    .0074526
  precip |   .0247312   .0082948     2.982   0.003       .0084737    .0409887
     feb |   .7560739   .1619445     4.669   0.000       .4386685    1.073479
     mar |  -.0149176    .198735    -0.075   0.940      -.4044311    .3745959
     apr |   .6522258   .2691511     2.423   0.015       .1246993    1.179752
     may |   1.994893   .3627646     5.499   0.000       1.283887    2.705899
     jun |   3.188733    .443878     7.184   0.000       2.318748    4.058718
     jul |   2.384609   .4746853     5.024   0.000       1.454243    3.314975
     aug |   1.684413   .4684913     3.595   0.000       .7661872    2.602639
     sep |   1.643346   .3905533     4.208   0.000       .8778753    2.408816
     oct |   .8113072   .2761011     2.938   0.003        .270159    1.352455
     nov |   1.094028   .2045293     5.349   0.000       .6931579    1.494898
     dec |     -.0019   .1488066    -0.013   0.990      -.2935555    .2897555
    year |  -.3719587   .0542995    -6.850   0.000      -.4783838   -.2655337
   _cons |   3.038365   .6528888     4.654   0.000       1.758726    4.318003
---------+--------------------------------------------------------------------
 sigma_u |  2.7504021
 sigma_e |  3.5793376
     rho |  .37124923   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. *Compare to logged model for dependent variable
. xtreg lnwater bathroom hous1000 housbath area1000 area2000 d_unit constr94 av
> etemp precip feb mar apr may jun jul aug sep oct nov dec year

Random-effects GLS regression                   Number of obs      =     20728
Group variable (i) : customer                   Number of groups   =       952

R-sq:  within  = 0.0632                         Obs per group: min =        12
       between = 0.2456                                        avg =      21.8
       overall = 0.1759                                        max =        23

Random effects u_i ~ Gaussian                   Wald chi2(21)      =   1652.13
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
 lnwater |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
bathroom |   .1837987   .0359769     5.109   0.000       .1132854     .254312
hous1000 |   .0033826   .0005391     6.275   0.000        .002326    .0044392
housbath |  -.0004989   .0001516    -3.291   0.001       -.000796   -.0002018
area1000 |   .0009531    .001727     0.552   0.581      -.0024318     .004338
area2000 |  -9.94e-06   .0000108    -0.923   0.356      -.0000311    .0000112
  d_unit |  -.3027544   .0572257    -5.291   0.000      -.4149147   -.1905942
constr94 |  -.0643248   .0483564    -1.330   0.183      -.1591016     .030452
 avetemp |   .0040527   .0013409     3.022   0.003       .0014246    .0066807
```

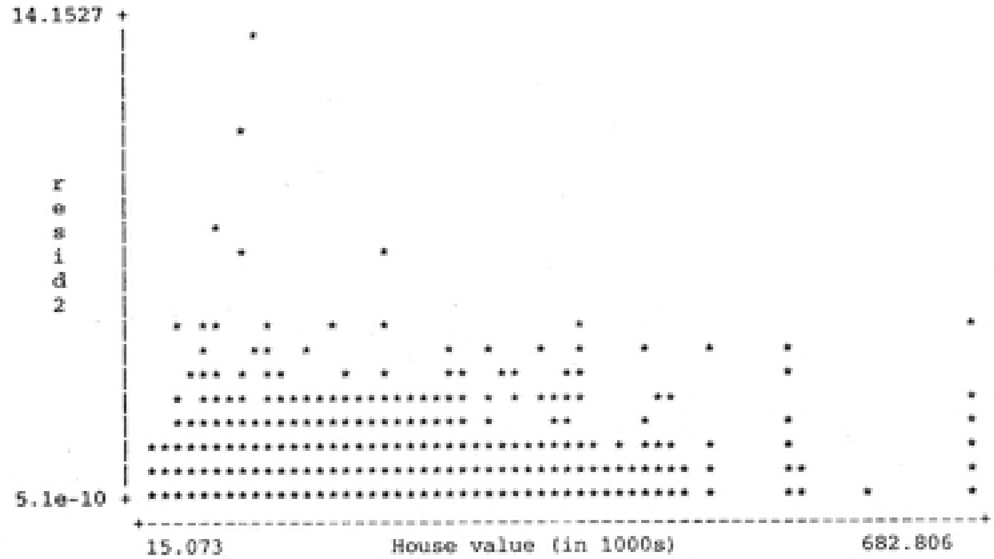
```
    precip |   .0046812   .0009786      4.783   0.000       .0027631    .0065993
       feb |   .1028741   .0191148      5.382   0.000       .0654098    .1403384
       mar |  -.1191265   .0234617     -5.077   0.000      -.1651106   -.0731423
       apr |  -.0228953   .0317854     -0.720   0.471      -.0851935    .0394028
       may |   .0615812   .0428655      1.437   0.151      -.0224337    .1455961
       jun |   .2027837   .0524233      3.868   0.000       .1000359    .3055316
       jul |   .0453858   .0560631      0.810   0.418      -.0644958    .1552674
       aug |  -.0373731   .0553299     -0.675   0.499      -.1458177    .0710715
       sep |   .0270381   .0461235      0.586   0.558      -.0633624    .1174385
       oct |  -.0065775   .0325994     -0.202   0.840      -.0704711    .0573162
       nov |    .092585   .0241468      3.834   0.000        .045258    .1399119
       dec |   .0072039   .0175716      0.410   0.682      -.0272357    .0416435
      year |  -.0192029   .0064159     -2.993   0.003      -.0317778    -.006628
     _cons |   .5629101   .0920422      6.116   0.000       .3825108    .7433094
-----------+--------------------------------------------------------------------
   sigma_u |  .45053962
   sigma_e |  .42163722
       rho |  .53310189   (fraction of variance due to u_i)
--------------------------------------------------------------------------------

. *More multicollinearity testing
. quietly reg wateruse bathroom hous1000 housbath area1000 area2000 d_unit constr94 ave
temp precip feb mar apr may jun jul aug sep oct nov dec year, cluster( customer)

. vif

Variable |       VIF       1/VIF
---------+----------------------
 avetemp |     38.86    0.025736
     aug |     28.76    0.034775
     jul |     28.57    0.034996
     jun |     21.29    0.046963
     sep |     20.16    0.049603
     may |     17.09    0.058513
housbath |     13.44    0.074382
     oct |     10.09    0.099099
hous1000 |     10.04    0.099603
     apr |      9.32    0.107250
     nov |      5.55    0.180180
area1000 |      5.24    0.190929
     mar |      5.00    0.200011
area2000 |      4.34    0.230561
bathroom |      3.47    0.288186
     feb |      3.38    0.295686
     dec |      2.93    0.341106
  precip |      2.36    0.423053
constr94 |      1.35    0.740640
  d_unit |      1.23    0.813742
    year |      1.17    0.851465
---------+----------------------
Mean VIF |     11.13

***************************************************************************
3:55 PM 6/23/01
. quietly regress  lnwater bathroom hous1000 housbath area1000 area2000 d_unit constr94
avetemp precip feb mar apr may jun jul aug sep oct nov dec year, cluster( customer)

. *If model is to be logged in dependent variable, then need smearing factors
. quietly regress  lnwater bathroom hous1000 housbath area1000 area2000 d_unit constr94
avetemp precip feb mar apr may jun jul aug sep oct nov dec year, cluster( customer)

. *computing the smearing factor - see pg 128 of Norton notes
. *compute predicted value for each observation in the subsample
. predict lnw_hat
(option xb assumed; fitted values)
(94518 missing values generated)

. *exponentiate the predicted values
. gen w_hat=exp( lnw_hat)
(94518 missing values generated)
```

```
. *square the root mean squared error, multiply by one half, then exponentiate
. gen w_hatnor=exp(lnw_hat+0.5*e(rmse)^2)
(94518 missing values generated)

. di exp(0.5*e(rmse)^2)
1.2150001

. *smearing
. predict double resid, residual
(94575 missing values generated)
. egen sm_err=mean(exp(resid))
. di sm_err
1.2104878

. *above smearing:  take all residuals from the regression, exponentiate them, add them
up and divide by the number of observations N.  should be similar to other number
(smearing factor is usually larger)

. graph resid, histogram

. *the results of the plot show that the distribution is skewed somewhat to the left,
hence the smearing factor is smaller
. *multiply the exponentiated predicted value from the first part by the smearing factor
in the second part
. gen w_hatsm=w_hat*sm_err
(94518 missing values generated)

. list w_hat w_hatnor w_hatsm in 1/10
          w_hat   w_hatnor    w_hatsm
  1.   3.621023   4.399543   4.383204
  2.   3.932619   4.778132   4.760387
  3.   4.049555    4.92021   4.901937
  4.   4.791645   5.821849   5.800228
  5.   3.822041   4.643779   4.626534
  6.   3.956636   4.807313    4.78946
  7.   3.811302   4.630732   4.613534
  8.   3.176367   3.859286   3.844953
  9.   3.510017   4.264671   4.248833
 10.   3.382393   4.109608   4.094346

*********************************************************************************
12:23 PM 6/25/01
. use "D:\regress2000.dta", clear
. gen housbath =  bathroom* hous1000
(51326 missing values generated)

****************************************
3:14 PM 6/25/01
. use "D:\regress.dta", clear

. *Heteroskedasticity testing
. quietly xtreg wateruse bathroom hous1000 housbath area1000 area2000 d_unit constr94
avetemp precip feb mar apr may jun jul aug sep oct nov dec year

. *predicts the combined residual, ui + eit
. predict resid, ue
(94575 missing values generated)

. *where ui = the fixed or random error component and eit = the overall error component
. gen resid2 = resid^2
(94575 missing values generated)
```

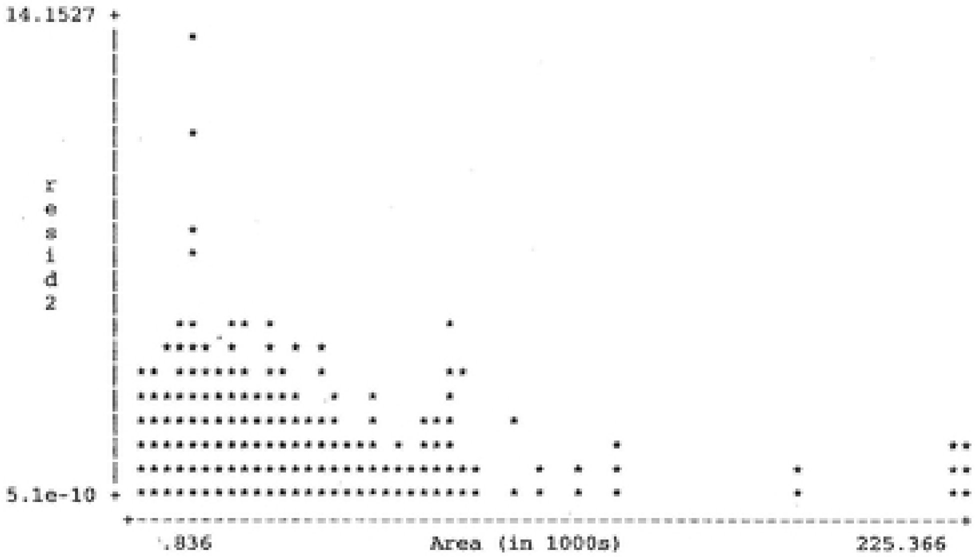
```
. *plots of squared residual vs independent variables
. plot  resid2 bathroom
```



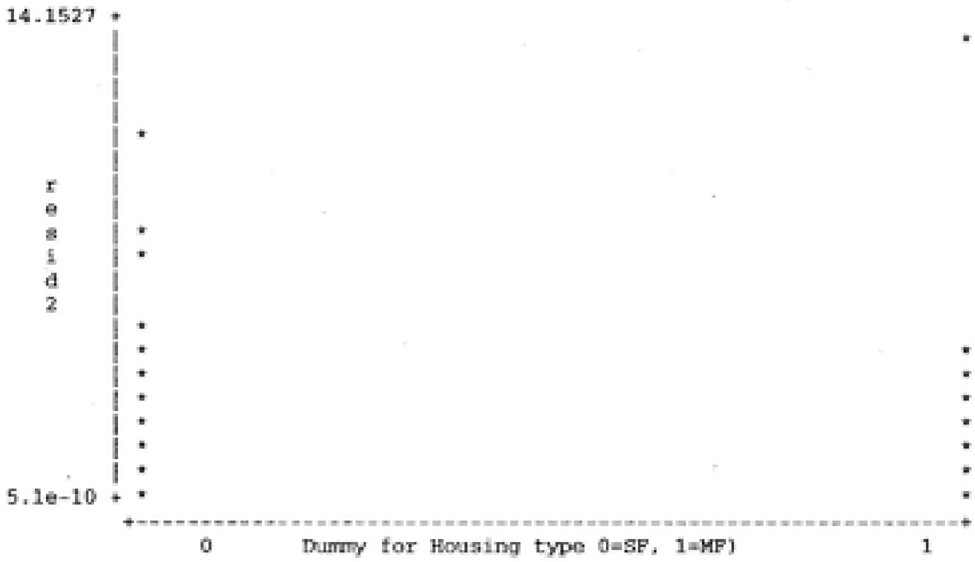

```
. plot  resid2 hous1000
```



```
. plot  resid2  area1000
```

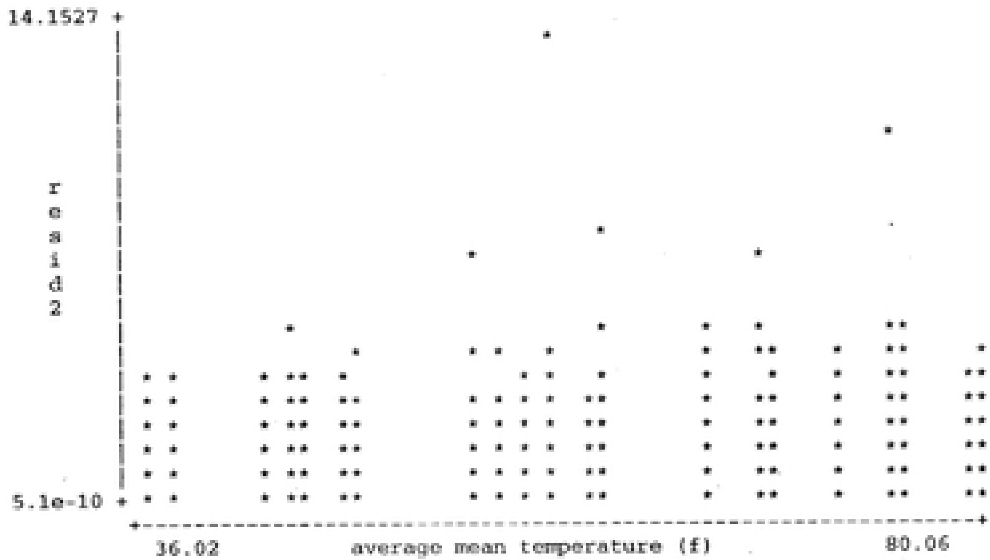



```
. plot  resid2 d_unit
```



```
. plot  resid2 constr94
```


```
. plot  resid2  avetemp
```



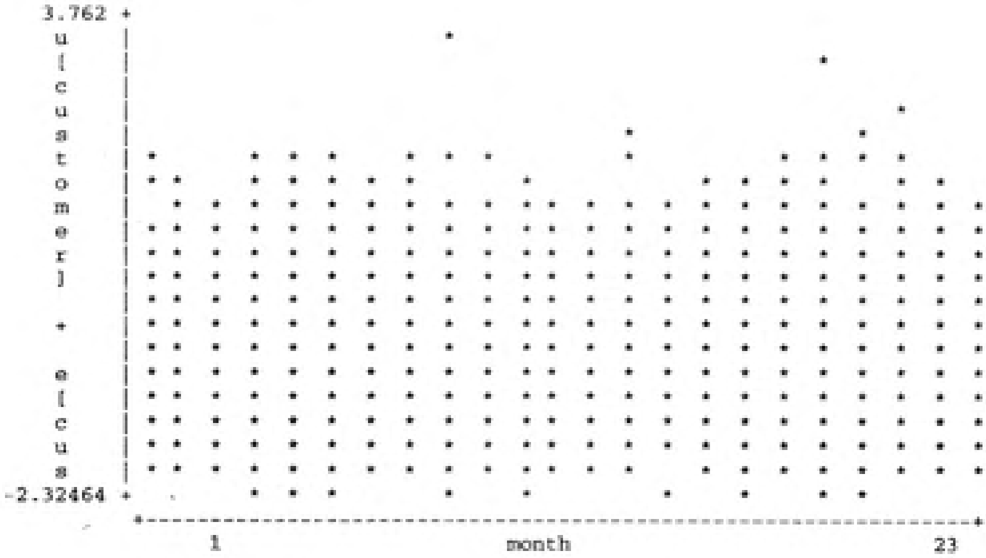
```
. plot  resid2 precip

 14.1527 +
         |       *
         |
         |
         |
         |
         |            *
         |
       r |
       e |
       s | *
       i |       *   *
       d |
       2 |
         | * *  * *  * *
         |  *  ***  * *      *                                            *
         | * ** ****  ***  *   *                                            *
         | * ** **** ****  *   *                                            *
         | * ** **** ****  *   *                                            *
         | * ** **** ****  *   *                                            *
         | * ** **** ****  *   *                                            *
 5.1e-10 + * ** **** ****  *   *                                            *
          +-----------------------------------------------------------------+
            .26              sum precipitation (in)               24.01
```

```
. *white test for heteroskedasticity
. xtreg resid2 bathroom hous1000 housbath area1000 area2000 d_unit constr94 avetemp
precip feb mar apr may jun jul aug sep oct nov dec year

Random-effects GLS regression                   Number of obs      =     20728
Group variable (i) : customer                   Number of groups   =       952

R-sq:  within  = 0.0197                         Obs per group: min =        12
       between = 0.0143                                        avg =      21.8
       overall = 0.0181                                        max =        23

Random effects u_i ~ Gaussian                   Wald chi2(21)      =    409.86
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000
```

resid2	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
bathroom	-.084017	.0265878	-3.160	0.002	-.136128	-.0319059
hous1000	-.000977	.0003985	-2.452	0.014	-.001758	-.000196
housbath	.0003713	.000112	3.315	0.001	.0001518	.0005908
area1000	.0017704	.001276	1.388	0.165	-.0007304	.0042713
area2000	-7.88e-06	7.95e-06	-0.990	0.322	-.0000235	7.71e-06
d_unit	.029865	.0423267	0.706	0.480	-.0530938	.1128239
constr94	.0113788	.0358047	0.318	0.751	-.0587972	.0815548
avetemp	-.0115902	.0016327	-7.099	0.000	-.0147902	-.0083902
precip	-.0016275	.0011917	-1.366	0.172	-.0039632	.0007082
feb	.0519773	.0232766	2.233	0.026	.006356	.0975987
mar	.1884624	.028569	6.597	0.000	.1324682	.2444566
apr	.2194372	.0387035	5.670	0.000	.1435796	.2952947
may	.4983476	.0521954	9.548	0.000	.3960465	.6006487
jun	.5073925	.0638316	7.949	0.000	.3822849	.6325002
jul	.5751171	.068265	8.425	0.000	.4413202	.7089141
aug	.536628	.0673729	7.965	0.000	.4045795	.6686764
sep	.4131951	.0561627	7.357	0.000	.3031183	.5232719
oct	.2263028	.0396959	5.701	0.000	.1485004	.3041053
nov	.1484369	.0294037	5.048	0.000	.0908067	.2060671
dec	-.0278266	.0213972	-1.300	0.193	-.0697643	.0141111
year	-.0726466	.0078085	-9.304	0.000	-.087951	-.0573423
_cons	.9985116	.0862893	11.572	0.000	.8293876	1.167636
sigma_u	.32150393					
sigma_e	.51376059					
rho	.28140657	(fraction of variance due to u_i)				

```
. *Park test for heteroskedasticity
. gen park = log( resid2)
(94575 missing values generated)

. xtreg park bathroom hous1000 housbath area1000 area2000 d_unit constr94 avetemp precip
feb mar apr may jun jul aug sep oct nov dec year

Random-effects GLS regression                   Number of obs      =     20728
Group variable (i) : customer                   Number of groups   =       952

R-sq:  within  = 0.0125                         Obs per group: min =        12
       between = 0.0101                                        avg =      21.8
       overall = 0.0119                                        max =        23

Random effects u_i ~ Gaussian                   Wald chi2(21)      =    260.08
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
    park |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
bathroom |  -.2149731   .0882167     -2.437   0.015      -.3878746   -.0420715
hous1000 |  -.0014243   .0013222     -1.077   0.281      -.0040157    .0011672
housbath |   .0005698   .0003715      1.534   0.125      -.0001584     .001298
area1000 |   .0044563    .004233      1.053   0.292      -.0038401    .0127528
area2000 |  -3.69e-06   .0000264     -0.140   0.889      -.0000554     .000048
  d_unit |    .059088   .1405074      0.421   0.674      -.2163014    .3344774
constr94 |   .0444755   .1189291      0.374   0.708      -.1886212    .2775723
 avetemp |   -.024898    .006363     -3.913   0.000      -.0373692   -.0124268
  precip |   .0017038   .0046445      0.367   0.714      -.0073993    .0108069
     feb |   .1861769   .0907169      2.052   0.040       .0083751    .3639787
     mar |   .5926174   .1113407      5.323   0.000       .3743937    .8108411
     apr |    .446649   .1508353      2.961   0.003       .1510173    .7422806
     may |   1.292661   .2034157      6.355   0.000       .8939731    1.691348
     jun |   1.158407   .2487598      4.657   0.000       .6708466    1.645967
     jul |   1.389665   .2660411      5.223   0.000       .8682339    1.911096
     aug |   1.221121   .2625659      4.651   0.000       .7065015    1.735741
     sep |   .9232853   .2188773      4.218   0.000       .4942937    1.352277
     oct |     .47911    .154705      3.097   0.002       .1758939    .7823262
     nov |   .4345842   .1145949      3.792   0.000       .2099824     .659186
     dec |  -.0258748   .0833915     -0.310   0.756      -.1893191    .1375695
    year |  -.2068807   .0304226     -6.800   0.000      -.2665079   -.1472536
   _cons |  -1.045157   .3172065     -3.295   0.001      -1.666871   -.4234439
---------+--------------------------------------------------------------------
 sigma_u |  1.0432048
 sigma_e |  2.0030739
     rho |  .21336319   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
. *Tests for Autocorrelation
. *graph the residuals vs time
. plot resid month
```




```
. plot  resid year
```


```
. *scattered above and below the x axis (i.e. x = 0) and not much of a cyclical pattern
. *appears that autocorrelation is not much of a problem, as there is no clear
oblong shape signifying positive or negative correlation
. *since there is no pattern, it is assumed that there is no autocorrelation, especially
since there are no negative residuals or residuals grouped below the x axis

. save "D:\regress.dta", replace
file D:\regress.dta saved

. *testing panel data form
. quietly xtreg wateruse bathroom hous1000 housbath area1000 area2000 d_unit con
> str94 avetemp precip feb mar apr may jun jul aug sep oct nov dec year
```

```
. xttest0
Breusch and Pagan Lagrangian multiplier test for random effects:

        wateruse[customer,t] = Xb + u[customer] + e[customer,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                wateruse |   .4721684       .6871451
                       e |   .1777779       .42163722
                       u |   .2029859       .45053962

        Test:   Var(u) = 0
                              chi2(1) = 63883.14
                          Prob>chi2 =     0.0000

. xthaus

Hausman specification test

                ---- Coefficients ----
         |      Fixed        Random
wateruse |     Effects       Effects       Difference
---------+---------------------------------------------
housbath |   -.0000667     -.0004989        .0004322
 avetemp |    .0040394      .0040527       -.0000132
  precip |    .0046718      .0046812       -9.47e-06
     feb |    .1029144      .1028741        .0000403
     mar |   -.1194738     -.1191265       -.0003474
     apr |    -.022983     -.0228953       -.0000877
     may |    .0615898      .0615812        8.60e-06
     jun |    .2033821      .2027837        .0005983
     jul |    .0456296      .0453858        .0002438
     aug |   -.0370447     -.0373731        .0003284
     sep |    .0273942      .0270381        .0003562
     oct |   -.0065503     -.0065775        .0000272
     nov |    .0925654       .092585       -.0000196
     dec |    .0068953      .0072039       -.0003086
    year |   -.0193617     -.0192029       -.0001588

Test:  Ho:  difference in coefficients not systematic

            chi2( 15) = (b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
                      =      0.00
            Prob>chi2 =      1.0000

. *if coefficients differ significantly, then the model is misspecified or the
assumption that the random effects vi are uncorrelated with the regressors xit is
incorrect
. *so in this case, we can not reject the null hypothesis that the coefficients
are the same, i.e. they do not differ significantly

. log close

******************************************************************************

12:04 PM 7/6/01

. use "D:\regress2000.dta", clear

. gen lntemp=ln( avetemp)
. gen lnbathhs =  lnbath* lnhouse
(51326 missing values generated)

. xtreg  wateruse lnbath lnhouse area1000 area2000 d_unit constr94 lntemp lnbathhs
raindays feb mar apr may jun jul aug sep oct nov dec

Random-effects GLS regression                   Number of obs      =     11164
Group variable (i) : customer                   Number of groups   =       952

R-sq:  within  = 0.0650                         Obs per group: min =         3
```

```
     between = 0.2263                                          avg =      11.7
     overall = 0.1503                                          max =        12

Random effects u_i ~ Gaussian                   Wald chi2(18)       =   4704.31
corr(u_i, X)       = 0 (assumed)                Prob > chi2         =    0.0000
```

wateruse	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnbath	-7.079052	1.780275	-3.976	0.000	-10.56833	-3.589778
lnhouse	.7525884	.3941783	1.909	0.056	-.0199868	1.525164
area1000	.0097615	.0107978	0.904	0.366	-.0114019	.0309249
area2000	-.0001035	.0000676	-1.532	0.126	-.0002359	.0000289
d_unit	-1.201675	.3602404	-3.336	0.001	-1.907733	-.4956167
constr94	-.1933989	.3031995	-0.638	0.524	-.787659	.4008611
lntemp	.2357069	.3991356	0.591	0.555	-.5465844	1.017998
lnbathhs	1.682769	.3770068	4.463	0.000	.943849	2.421688
raindays	-.0449791	.0154296	-2.915	0.004	-.0752205	-.0147377
feb	-.6633593	.1335027	-4.969	0.000	-.9250197	-.4016988
mar	-.2275639	.1318479	-1.726	0.084	-.4859812	.0308533
apr	.3147771	.2056513	1.531	0.126	-.088292	.7178462
may	.7564201	.1673868	4.519	0.000	.428348	1.084492
jun	2.100365	.2553876	8.224	0.000	1.599814	2.600915
jul	.6367938	.2786244	2.285	0.022	.0907	1.182888
aug	1.212595	.2619638	4.629	0.000	.6991551	1.726034
sep	.6405529	.2546868	2.515	0.012	.1413758	1.13973
oct	(dropped)					
nov	1.473325	.1377422	10.696	0.000	1.203356	1.743295
dec	-.5182046	.1722302	-3.009	0.003	-.8557697	-.1806396
_cons	(dropped)					
sigma_u	2.7200731					
sigma_e	3.1751912					
rho	.42325676	(fraction of variance due to u_i)				

```
. reg  wateruse lnbath lnhouse area1000 area2000 d_unit constr94 lntemp  lnbathhs
raindays feb mar apr may jun jul aug sep oct nov dec, cluster( customer)

Regression with robust standard errors                 Number of obs =   11164
                                                       F( 18,    951) =   36.26
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1503
Number of clusters (customer) = 952                    Root MSE      =  4.1814
```

wateruse	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnbath	-7.22903	3.001957	-2.408	0.016	-13.12026	-1.337804
lnhouse	.7626217	.5422078	1.407	0.160	-.3014402	1.826684
area1000	.0094381	.0105678	0.893	0.372	-.0113009	.0301771
area2000	-.0001022	.00007	-1.460	0.145	-.0002396	.0000352
d_unit	-1.222233	.2732991	-4.472	0.000	-1.758572	-.6858936
constr94	-.1844298	.3461043	-0.533	0.594	-.8636462	.4947866
lntemp	(dropped)					
lnbathhs	1.711449	.6739828	2.539	0.011	.3887833	3.034114
raindays	-.0540733	.0079084	-6.837	0.000	-.0695932	-.0385534
feb	-.7031214	.0853664	-8.237	0.000	-.8706498	-.5355931
mar	-.2053463	.1195188	-1.718	0.086	-.4398974	.0292048
apr	.421132	.0849796	4.956	0.000	.2543628	.5879013
may	.8094796	.0966008	8.380	0.000	.6199043	.9990549
jun	2.23703	.1597593	14.003	0.000	1.923508	2.550551
jul	.7779821	.1592369	4.886	0.000	.4654859	1.090478
aug	1.354155	.1954206	6.929	0.000	.9706498	1.73766
sep	.7726913	.1255881	6.153	0.000	.5262295	1.019153
oct	(dropped)					
nov	1.514629	.1252075	12.097	0.000	1.268914	1.760343
dec	-.5631887	.0791028	-7.120	0.000	-.7184248	-.4079525
_cons	.9591069	2.196974	0.437	0.663	-3.352371	5.270585

```
. xtreg  wateruse hous1000 d_unit constr94 avetemp raindays jan mar apr may jun
>  jul aug sep oct nov dec

Random-effects GLS regression                   Number of obs      =     24628
Group variable (i) : customer                   Number of groups   =      2087

R-sq:  within  = 0.1045                         Obs per group: min =         3
       between = 0.2756                                        avg =      11.8
       overall = 0.1923                                        max =        12

Random effects u_i ~ Gaussian                   Wald chi2(14)      =  11607.02
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
wateruse |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
hous1000 |   .0205047   .0007876     26.034   0.000        .018961    .0220484
  d_unit |  -1.161783   .3120642     -3.723   0.000      -1.773418   -.5501486
constr94 |  -.4980279   .1601661     -3.109   0.002      -.8119478    -.184108
 avetemp |   .0199468   .0046372      4.301   0.000       .0108581    .0290355
raindays |   .0411854   .0111387      3.698   0.000       .0193539    .0630169
     jan |  (dropped)
     mar |   .4697603   .1473729      3.188   0.001       .1809148    .7586059
     apr |   .4879182   .1311261      3.721   0.000       .2309157    .7449207
     may |   2.161529   .2180486      9.913   0.000       1.734161    2.588896
     jun |   3.565235   .2065131     17.264   0.000       3.160477    3.969993
     jul |   1.366358   .1991228      6.862   0.000       .9760848    1.756632
     aug |   1.584608    .198602      7.979   0.000       1.195355     1.97386
     sep |   1.023816   .1688775      6.062   0.000       .6928224     1.35481
     oct |   1.656078   .2067669      8.009   0.000       1.250822    2.061334
     nov |   2.546185   .1101456     23.117   0.000       2.330303    2.762066
     dec |   .3517621   .1042324      3.375   0.001       .1474704    .5560538
   _cons |  (dropped)
---------+--------------------------------------------------------------------
 sigma_u |  3.1719927
 sigma_e |  3.8147054
     rho |  .40878101   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. reg  wateruse hous1000 d_unit constr94 avetemp raindays jan mar apr may jun j
> ul aug sep oct nov dec, cluster(customer)

Regression with robust standard errors                 Number of obs =   24628
                                                       F( 14,  2086) =   91.49
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1923
Number of clusters (customer) = 2087                   Root MSE      =  4.9697

------------------------------------------------------------------------------
         |               Robust
wateruse |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
hous1000 |   .0205809   .0012623     16.304   0.000       .0181053    .0230564
  d_unit |  -1.168903   .2150659     -5.435   0.000      -1.590669   -.7471367
constr94 |  -.4972156   .1748992     -2.843   0.005      -.8402107   -.1542205
 avetemp |   .0582432   .0037074     15.710   0.000       .0509726    .0655138
raindays |   .0708891   .0068915     10.286   0.000       .0573742    .0844039
     jan |  (dropped)
     mar |   .1890095   .0826909      2.286   0.022       .0268443    .3511748
     apr |  -.1943161   .0768257     -2.529   0.012      -.3449792    -.043653
     may |   1.312714   .0997496     13.160   0.000       1.117095    1.508333
     jun |   2.250481   .0957857     23.495   0.000       2.062635    2.438326
     jul |  (dropped)
     aug |    .281936   .1195133      2.359   0.018       .0475583    .5163137
     sep |  -.0863491   .1140094     -0.757   0.449      -.3099331    .1372349
     oct |   1.258545    .113982     11.042   0.000       1.035015    1.482076
     nov |   2.326017    .113023     20.580   0.000       2.104367    2.547666
     dec |   .6915113   .0792938      8.721   0.000       .5360081    .8470145
   _cons |  -1.938003   .3799458     -5.101   0.000      -2.683115    -1.19289
------------------------------------------------------------------------------
```

The purpose of this appendix is to describe a simple method to estimate rates for conservation pricing. Some background information is presented to demonstrate findings in the literature, and then seasonal pricing calculations are described.

Numerous econometric studies have been performed to analyze the effect of conservation policies on water use (Billings et al., 1989; Espey et al., 1997; Michelsen et al., 1999; Nieswiadomy, 1992; Wang et al., 1999). Many policies involve public outreach education programs or pricing strategies such as the seasonal pricing option that OWASA has proposed. It is widely known that consumers respond negatively to increases in price, but these reports test that theory in the water field. One criterion for estimating the response in quantity demanded to changes in price is the price elasticity of demand, which can range from perfectly inelastic (i.e. the customer does not change consumption at all due to changes in price) where elasticity is zero to highly elastic where (the absolute value of) elasticity is greater than one. If demand is inelastic, an increase in price causes revenue to increase, which is the typical situation in community water supply.

Espey et al. (1997) found that summer demand is more elastic than winter demand; hence, customers respond more to price increases in summer. To be effective, conservation pricing should be designed to reduce consumption in summer since prices would not have to be raised as much as in winter. OWASA has already implemented this concept in their seasonal pricing scheme.

Typical price elasticity of demand for water ranges from -0.3 to -0.7 in the literature. A price elasticity of -0.3 indicates that for every one percent increase in price, water consumption decreases by 0.3 percent. This range is used herein for a sensitivity analysis of seasonal pricing effects.

The following assumptions are made for this analysis:

- Summer months include May to September
- Winter months include October to April
- The concern with seasonal pricing is for summer only

- Multi-family households with master meters are not considered as their bill is paid by others and hence they (presumably) have highly inelastic demand
- Price elasticities are based on literature reviewed, and range from -0.3 to -0.7
- Price increases are based on OWASA's current flat price of $2.90 per 1,000 gallons
- Summer consumption is based on year 2000 data (see Table J.1)
- Revenue calculations are based on consumption for year 2000
- Number of residential households is based on study Population (i.e. 13,000)

Table J.1 – Average Household Consumption for Year 2000

	Total Consumption (1,000 gal/mo/HH)
January	4.96
February	4.85
March	5.32
April	5.43
May	***6.36***
June	***6.84***
July	***5.68***
August	***6.23***
September	***5.82***
October	5.76
November	6.52
December	4.84

Note: months in ***bold italics*** are summer months.

Average summer consumption in year 2000 using values from Table J.1 is approximately 6,200 gallons per month per household (gal/mo/HH), and average winter consumption is approximately 5,400 gal/mo/HH. Price elasticity applies to the total household consumption. Price elasticity, η, is defined as follows:

$$\eta = \frac{dq/q}{dp/p} = \frac{\text{change in quantity demanded/quantity}}{\text{change in price/price}} = \frac{\text{\% change in quantity demanded}}{\text{\% change in price}}$$

Assume that OWASA wants a target reduction of 500 gallons per month per household in summer, then

$$\frac{dq}{q} = \frac{-500}{6,200} = -0.08$$ (i.e. an 8% reduction in quantity demanded)

In order to calculate the corresponding increase in price, the equation for price elasticity is rearranged:

$$\%\text{ change in price} = \frac{\%\text{ change in quantity demanded}}{\text{price elasticity, }\eta}$$

Using a price elasticity of -0.5, $\%\text{ change in price} = \frac{-8\%}{-0.5} = +16\%$. Using the current flat price of $2.90 per 1,000 gallons, a 16 percent increase in price corresponds to a new summer price of $3.37 per 1,000 gallons.

Table J.2 shows the price increases necessary to achieve a 500 gal/mo/HH reduction in summer consumption for a range of price elasticity values.

Table J.2 –Price Increases and New Summer Prices ($ per 1,000 gallons) for Range of Elasticity Values

Elasticity	Increase in Price	New Summer Price (per 1,000 gallons)	Δ Price = New – Current (per 1,000 gallons)
-0.3	27 %	$3.68	$0.78
-0.4	20 %	$3.48	$0.58
-0.5	16 %	$3.37	$0.47
-0.6	13 %	$3.29	$0.39
-0.7	12 %	$3.23	$0.33

Implementing seasonal pricing increases revenue in the summer. Revenue is also increased overall if winter prices are not decreased. Total revenue generated with the various alternatives can be calculated to determine either the increase in total revenue or the new lower winter price to maintain original revenue. Table J.3 shows the original revenue for summer, using average household consumption (i.e. summer revenue = 13,000 households * 6,200 gal/mo/HH * $2.90/1000 gallons * 5 months). Total summer consumption with the current price is about 400 million gallons (= 13,000 households * 0.0062 million gallons/HH).

Table J.3 – Total Summer Revenue with Original Price of \$2.90 per 1,000 gallons

Average Consumption (gal/mo/HH)	Total revenue (\$M)
6,190	1.17

Table J.4 shows the new revenue using average total consumption with the 500 gal/mo/HH reduction and new seasonal pricing. Calculations are for a price elasticity of -0.5, as shown above. Comparing the total revenue for summer, there is approximately a 6 percent increase due to the price increase form \$2.90 to \$3.37 per 1,000 gallons.

Table J.4 – Total Summer Revenue with New Price of \$3.37 per 1,000 gallons

Total Consumption (gal/mo/HH)	Total revenue (\$M)
5,690	1.25

As OWASA is primarily not interested in generating more revenue, it is possible to decrease winter rates in order to keep revenue constant. If winter pricing were to be adjusted to compensate for this increase, several things need to be considered. As winter price decreases, consumption increases. However, winter consumption is usually less elastic and may not change as much as summer with a decrease in price (Espey et al., 1997), as it is mainly indoor use. This means that if an elasticity of -0.5 is chosen for the summer, winter elasticity would likely be say -0.3 or -0.4. Calculations for winter revenue are not included in this appendix.

As OWASA has already proposed seasonal rates to be implemented next year, it is interesting to examine the change in consumption associated with these new rates. OWASA's proposed seasonal rates are \$4.08 per 1,000 gallons in summer and \$2.16 per 1,000 gallons in winter. The change in price for the summer is $\frac{dp}{p} = \frac{(4.08 - 2.90)}{2.90} = 41\%$ and for the winter is $\frac{dp}{p} = \frac{(2.16 - 2.90)}{2.90} = -26\%$.

The decrease in consumption is expressed as: % change in quantity demanded = % change in price * price elasticity. Using a price elasticity of -0.5, the corresponding consumption decrease for the summer is 20% (= 41% * -0.5). A 20 percent decrease in consumption would lead to a reduction of about 1,260 gallons per month per household; consumption would be reduced from its current level of about 400 million gallons to about 320 million gallons per summer.

Table J.5 shows the expected decrease or increase in consumption using a range of elasticity values for the proposed summer and winter prices, respectively.

Table J.5 – Change in Consumption (gallons per month per household) with OWASA's Proposed Seasonal Prices

	Summer Consumption			*Winter Consumption*		
Elasticity	**% Change**	**New**	**Δ = New - Current**	**% Change**	**New**	**Δ = New - Current**
-0.3	-12	5,400	760	+8	5,800	-410
-0.4	-16	5,200	1,000	+10	5,900	-550
-0.5	-20	4,900	1,300	+13	6,000	-690
-0.6	-24	4,700	1,500	+15	6,200	-820
-0.7	-28	4,400	1,800	+18	6,300	-960